THE

EMPORIUM

OF

ARTS AND SCIENCES.

VOL. I.

(NEW SERIES.)

CONTENTS.

PROSPECTUS

OF THE

EMPORIUM

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(NEW SERIES.)

THE Emporium hitherto published, having been relinquished by its Editor and Publisher, I have undertaken to continue it under the same title; and the public will of course expect that I should give some account of the plan on which it is meant hereafter to be conducted.

I do not see, at present, any material objection to the plan originally proposed by Dr. Coxe: for what more useful work could the public desire, than one which should contain a judicious *selection* of practical papers on manufactures and the arts, from the more scarce and voluminous among the foreign publications, and a *repository* for original papers of the same description, furnished by men of research in our country?

I had prepared a volume of papers on manufacturing processes, which the publishers of the present work were to have published separately, had not the new series of the Emporium been undertaken. The matter I had meant for that work, I shall now employ upon this; and I will make, if I can, the Emporium a repository of papers on manufactures, that shall be worth preserving. They will consist of a series of essays drawn up and arranged by myself, but with the assistance of every thing

I can find to the purpose in foreign publications. I have long been anxious to compose and to compile a work of this description, that shall remain a classic book on the subject, and I will endeavour to do it now.

In treating of the various subjects, it will be fair to give notice, that I will not condescend to make this a work of mere amusement, for the purpose of sale—one that shall suffice merely, under the show of science, to enable the reader to trifle away an hour, and to skim the surface of a great many subjects for the purpose of superficial and conversation knowledge. Many pages of this work to a general reader will be very dull; but it will be my fault if they are not useful to those who read for improvement.

I do not propose in the manufacturing papers I shall present, whether of my own or of others, greatly to instruct a manufacturer—a man who knows his business; or, by a sudden miracle, to form a skilful manufacturer by the perusal of a few theoretical pages. I know too well, from my own experience, that this cannot be done; and, I can easily conceive, with what contempt a practical man must read a great portion of the papers that pretend to give knowledge of real processes, among the French and English publications of this description. What innumerable instructions on the art of dying, for instance! yet I can venture to say, that hardly one paper in fifty contains either the processes of practice, or any kind of applicable information. Still the collectors of these facts are of great use in society: if they fail, it is because they are not themselves manufacturers; and because all manufacturers are secret-mongers, who live by their processes, and who do not choose to expose them to all the world. But many hints of importance are thus thrown out to those whose previous knowledge enables them to convert such hints to useful purposes: many

lights are thus thrown on the rationale of manufacturing processes, which will enable a practical man better to understand the nature and effect of the processes he has been accustomed to use, and to correct and vary them without depending upon chance whether he be wrong or right.

Moreover, there is hardly a manufacture that is not capable, in some way or other, of improving and throwing light upon some other manufacture, in appearance widely different. The art of the watchmaker has very greatly contributed to the perfection of the cotton machines. Scheele's discovery of the oxy-muriatic acid, has added one fourth to the capital of all the bleachers and callico-printers of Great Britain; the theory of Lavoisier gave rise to D'Argand's lamp; the experiments on the distillation of pit coal for coal tar, promise fair to furnish a better, a brighter, a safer, a cheaper light, than any other known combustible; the barometer has greatly improved the steam engine, and the water blast of the British iron works; the application of steam has, in England, changed the face of the dye house, the distillery, and the soap manufactory; it has improved the cooking apparatus of the kitchen, it has warmed the public buildings, it has been converted into a medicinal application of great importance,—while the steam engine itself has given incalculable force and facility to the manufactures of the kingdom, nearly without exception.

In almost all this knowledge, and in this application of it, as in a thousand similar instances that might be added to this short list, our own country is yet behindhand, and has yet to learn.

Moreover, papers that would be considered as of no great moment in that manufacturing country, will be of use in this. In the infancy of our manufacturing establishments, the conductors of them have to feel their path,

to tread cautiously, to reflect anxiously, and lights become important in the midst of darkness that would be unseen or unnoticed in the blaze of day.

Having been much occupied in chemical pursuits, and much conversant with manufactures and manufacturers, I feel myself as well qualified as most men, to select such information as in some way or other will be worth attention, but which also will require, as I hope it will generally repay, attention. Making this a stock-book for papers of value on the manufactures and the arts, I must be greatly indebted to other publications, and frequently to publications well known: frequently too, I shall have to republish in pursuit of my plan, what may have been already published by myself or others. If I make this work, as I mean to do, *the repository* for this kind of information, I must do so. No man can pretend to be original throughout a work on this extensive plan; it will be well conducted if he select judiciously.

Whether it be worth while to *encourage* manufactures in this country, or to turn aside a part of the capital from the immediate employment of agriculture is a question of great moment. All bounties and protecting duties, are taxes upon the rest of the community, in support of that employment of capital, which, without them, would be injudicious and unproductive. While so much land remains uncultivated, there can be no want of opportunities of employing capital in America. Generally speaking also, the interference of government is sadly misplaced, when it attempts to direct the capitalist what he shall do with his money. *Laissez nous faire*, is the proper reply. Still, there are considerations of great weight with me, in opposition to this general reasoning, that I have never seen urged.

1st. Our population is becoming scattered over such an extent of territory, that the nation is really weakened

by it; defence is more difficult and expensive; active hostility almost impossible; the communication of society, and of course of knowledge, is greatly retarded; many of our citizens are tempted to live in a half savage state; and even the administration of law, and the maintenance of order and necessary subordination, is rendered imperfect, tardy, and expensive.

2dly. Our agriculturists want a *home* market: manufactures would supply it. Agriculture at great distances from seaports, languishes for want of this. Great Britain exhibits an instance of unexampled power and wealth, by means of an agriculture greatly dependent on a system of manufacture: and her agriculture, thus situated, is the best in the world, though still capable of great improvement.

3dly. We are too much dependent upon Great Britain for articles that habit has converted into necessaries. A state of war demands privations that a large portion of our citizens reluctantly submit to. Home manufactures would greatly lessen the evil.

4thly. By means of debts incurred for foreign manufactures, we are almost again become colonists: we are too much under the influence, indirectly, of British merchants and British agents: we are not an independent people. Manufactures among us would tend to correct this, and give a stronger tone of nationality at home. I greatly value the intercourse with that country, of pre-eminent knowledge and energy, but our dependence upon it is often so great, as to be oppressive to ourselves.

5thly. The state of agriculture would improve with the improvement of manufactures, by means of the general spirit of energy and exertion which no where exists in so high a degree as in a manufacturing country; and by the general improvement of machinery, and the demand of raw materials.

6thly. The introduction of manufactures would extend knowledge of all kinds, particularly scientifical. The elements of natural philosophy and of chemistry, now form an indispensable branch of education among the manufacturers of England. They cannot get on without it. They cannot understand or keep pace with the daily improvements of manufacture without scientific knowledge: and scientific knowledge is not insulated; it must rest upon previous learning. The tradesmen of Great Britain, at this day, can furnish more profound thinkers on philosophical subjects, more acute and accurate experimenters, more real philosophers thrice told, than all Europe could furnish a century ago. I wish that were the case here; but it is not so. I fear it is not true, that we are the most enlightened people upon the face of the earth; unless the facility of political declamation be the sole criterion of decision, and the universal test of talent. We should greatly improve, in my opinion, by a little more attention to mathematical and physical science; I would therefore encourage whatever would introduce a general taste for such pursuits.

7thly. Because the home trade, consisting in the exchange of agricultural surplus for articles of manufacture produced in our own country, will for a long time to come, furnish the safest, and the least dangerous, the least expensive, and the least immoral—the most productive and the most patriotic employment of surplus capital, however raised and accumulated. The *safest*, because it requires no navies exclusively for its protection: the least *dangerous*, because it furnishes no excitement to the prevailing madness of commercial wars: the least *expensive*, for the same reason that it is the safest and the least dangerous: the least *immoral*, because it furnishes no temptation to the breach or evasion of the laws; to the multiplication of oaths and perjuries; and to the consequent prostration of

all religious feeling, and all social duty: the most *productive*, because the capital admits of quicker return; because the whole of the capital is permanently invested and employed at home; because it contributes directly, immediately, and wholly, to the internal wealth and resources of the nation: because the credits given, are more easily watched, and more effectually protected by our own laws, well known, easily resorted to, and speedily executed, than if exposed in distant and in foreign countries, controuled by foreign laws and foreign customs, and at the mercy of foreign agents: the most *patriotic*, because it binds the persons employed in it, by all the ties of habit and of interest, to their own country; while foreign trade tends to denationalize the affections of those whose property is dispersed in foreign countries, whose interests are connected with foreign interests, whose capital is but partially invested at the place of their domicil, and who can remove with comparative facility from one country to another. The wise man observed of old, that "where the treasure is, there will the heart be also," and time has not detracted from the truth of the remark.

Nor can there be any fear that for a century to come, there will not be full demand produced by a system of home manufacture, for every particle of surplus produce that agriculture can supply. Consider for a moment what are the articles that may fairly be regarded as of the first necessity, that an agricultural capitalist will require either to conduct his business, or for his reasonable comforts. 1st. The *iron manufacture* in all its branches from the ore to the boiling pans, the grate, the stove, the tire, the ploughshare, the spade, the scythe, the knife and fork, the sword and the gun: the *copper manufacture*, for his distilling vessels; for the bolts and sheathing of ships: the *lead manufacture*, for his paints and his shot: the *tin manufacture*, for his kitchen utensils; the manufacturing of powder

for blasting and for fire arms: he cannot dispense with the wheel-wright, the mill-wright, the carpenter, the joiner, the tanner, the currier, the sadler, the potter, the glass maker, the spinner, the weaver, the fuller, the dyer, the shoemaker, the hatter, the maker of machines and tools, and very many trades and handicrafts not enumerated. Of all these occupations, every one of which may be employed in furnishing articles either of immediate necessity of reasonable want, or of direct connection with agriculture, we have in abundance the raw materials of manufacture, and the raw material, uninstructed man to manufacture them. Is it to be pretended that these occupations when fully under way at home, will not furnish a market for the superfluous produce of agriculture, provided that produce be, as it necessarily will be, suited to the demand? Or ought this variety of occupation, and above all, the mass of real knowledge it implies, to be renounced and neglected for the sake of foreign commerce—that we may not interfere with the profits and connexions of the merchants who reside among us, and that we may be taxed and tolerated and licensed to fetch from abroad, what we can with moderate exertion supply at home? And yet this is the doctrine not merely advocated and recommended among us, but likely to become the fashionable creed of political economy, wherever mercantile interests and connections prevail. It appears to me of national importanc to counteract these notions. As a source of national wealth, I would no more encourage manufacture than I would encourage commerce—I would encourage or discourage neither: for I am persuaded that the aggregate of individual, constitutes national wealth; and that a government is conceited and presumptuous, when it attempts to instruct an individual how he can employ his industry and his capital most beneficially for his own interest.

Every treatise on political economy ought to have its

first page occupied with the answer to Colbert, LET US ALONE.

But as a mean of national defence, and national independence—as a mean of propagating among our citizens the most useful and practical kinds of knowledge—as a mean of giving that energetic, frugal, calculating and foreseeing character to every branch of our national industry, that does not exist but among a manufacturing people—as a mean of multiplying our social enjoyments by condensing our population—and as a mean of fixing the consumers and the producers in the immediate neighbourhood of each other—I would encourage the commencement at least of home manufacture. Not the manufacture of gold and silver—not the velvets of Lyons or the silks of Spitalfields---the laces of Brussels and the lawns of Cambray---not the clinquaillerie and bijouterie of Paris and Birmingham, but such as we feel the want of in time of war; such as may fairly be regarded as of prime necessity, or immediately connected with agricultural wants and pursuits.

8thly. I would remark, that nature seems to have furnished the materials of manufacture more abundantly in Pennsylvania in particular, than in any country I know of. The very basis of all profitable manufacture, is plenty of fuel, easily, cheaply, and permanently procurable: the next desirable object, is plenty of iron ore; iron being the article upon which every other manufacture depends. It is to the plentiful distribution of these two commodities, that Great Britain is chiefly indebted for the pre-eminence of her manufactures and her commerce. I have not a doubt on my mind, but both pitcoal, and iron ore, are more plentifully distributed in Pennsylvania than in Great Britain; and that both the one and the other can be gotten at more easily and cheaply in this country, than in that. Moreover we have a decided superiority in the raw materials of Cotton, Hemp and Flax; in our alkalies for glass

works; in the hides and the tanning materials of the leather manufactory; and we can easily procure that advantage, so far at least as our own consumption requires it, in the woollen manufactory. Other branches might be enumerated wherein our advantages of internal resource are undeniable; but I cannot see why we should neglect or despise these. Nothing but a stimulus is wanted to induce and enable us to make a proper use of our domestic riches. But men of skill and men of capital, fear to begin; lest on the return of peace, they should be exposed in the weakness and infancy of their undertaking, to contend with the overwhelming capital, and skill of the European powers, particularly of Great Britain.

For these reasons, I think it would be expedient so far to aid the introduction of manufactures in this country, by protecting duties, as to afford a reasonable prospect of safety to the prudent investment of capital, and the industrious pursuit of business; but no bounty to wild speculation, to negligent workmanship, or to smuggling.

But I must not forget, that for a book to be useful, it must be saleable. However desirous, therefore, I may be of making this a stock book for papers on the arts and manufactures, I shall not so crowd it with dry detail, and with matter but partially interesting, as to leave no room for miscellaneous information of a more general nature. I shall be glad to introduce notices of our own inventions and improvements, and descriptions of our own rising manufactures. I shall be very glad to receive and insert articles of this kind, and generally any original paper which I may deem worthy of the public eye. Communications of this description, post paid, to myself or the publishers, Kimber and Richardson, of Philadelphia, will be honestly attended to.

THOMAS COOPER.

Carlisle, February, 1813.

CONDITIONS.

The Emporium of Arts and Sciences will be published, in numbers, every two months, each number containing appropriate and well executed engravings, and about one hundred and fifty pages of letter press.

The price of the Emporioum will be seven dollars per annum, one half to be paid every six months.

No subscription will be taken for less than a year.

Subscriptions will be received by the publishers, Kimber and Richardson, No. 237, Market Street, Philadelphia; and Alexander & Phillips, Carlisle.

I have inserted the prospectus in this number, as containing the proper reasons for undertaking it, and the plan on which I mean (if I can) to conduct it. To the prospectus as originally published, I have made some additional observations in favour of a system of home manufacture. I have done so, on purpose that I may express my dissent from the doctrines contained in a work, greatly praised and recommended in the American review for October 1812, viz. *An inquiry into the various systems of political economy, their advantages and disadvantages, and the theory most favourable to national wealth, by* Charles Ganilh, *Advocate. Translated from the French by* D. Boileau, *author of an introduction to Political Economy.* New-York. Bradford and Inskeep, Philadelphia.

The means of encreasing national wealth, the importance of foreign trade, the necessity of attending to the balance of trade, and the excess of export above import, and much fact and reasoning relating to this subject, will be found in the writings of Dr. Davenant, Mr. Gee, Sir Josiah Child, &c. about the time of King William and Queen Ann; and many facts and arguments are adduced by these writers well worth notice in the present day. Indeed I much wish a collection were made and republished of

scarce tracts on commerce and political economy, in which these authors, and Sir W. Petit's tracts should be included. There is also a very good paper in the stile of the day, by Addison, supposed to be written for the Spectator, by Sir Andrew Freeport, the merchant of his club. The essays of Hume, and Sir James Steuart, next succeeded in England; essays of sterling merit on difficult questions of political economy.

In the mean time, Dr. Quesnay, in France, first propagated the doctrine that agriculture and agricultural labour, was the sole productive labour, and the only source of revenue: that every other species of labour was employed not in creating produce, like agriculture, but in changing the form of that which agriculture had produced. Quesnay was the founder of a new Sect, the *Economistes*, who may claim as associates, the two Mirabeaus, father and son, Turgot, Condorcet, La Riviere, and many others; and in part, the later economistes in that language, de Casaux, Herrenschwand, Garnier, Canard, &c.*

At length arose Adam Smith, who in his "Wealth of nations," developed the principles of the economistes, and fortified their general positions with facts and arguments, so clear, so strong, so luminously urged, and so well systematized, that from the time of its publication to the present day, it has been, and will in the future, as I think continue to be, *the book* on the subject of political econo-

* Mirabeau l'aine. Ami des hommes.

Mirabeau le jeune. Various passages in his Monarchie Prussienne.

Turgot, Condorcet. See Condorcet's Life of Turgot.

Mercier de la Riviere, Ordre naturel des Societes politiques.

De Casaux. Sur le mechanisme des societes, &c.

Herrenschwand. Discours fondamental sur la population. Ganilh has cited this work.

Discours sur le Commerce exterieur.

la division des Terres.

Canard and Garnier are frequently noticed by Ganilh; the authors above mentioned, are not noticed by him so far as I observe.

my. No man ought to pretend to knowledge on this subject, who has not studied Adam Smith's volumes. Since his time, the generality of English writers have adopted the leading principles of the economistes, but with variations as to the productive nature of manufactures and commerce; such as Arthur Young, Crumpe, Anderson, W. Vaughan, Lord Lauderdale, &c.

The particular value of *foreign* compared with *domestic* commerce, or the home trade, has not been sufficiently agitated. Some desultory remarks are to be found scattered among the numbers of Young's annals of agriculture. In the latter end of the year 1799, I undertook briefly to discuss this question, not knowing of any regular investigation of it in England. That essay I shall republish. Some years afterward, the same side of the question was taken up by Mr. Spence and Mr. Cobbett. Spence's pamphlet, *Great Britain Independent of Commerce*, (1808) has not agreed with the meridian of British politics either in that country or in this; but it contains much matter worthy of reflection. Those who defend the mercantile system of foreign commerce, are universally hostile to it; but it will stand its ground.

The work of Mr. Say I have never seen. Nor did I meet with Ganilh, until I perused the laboured panegyric, on it, in Mr. Walsh's review. The public are obliged to that gentleman, for giving notoriety and circulation to a book written with undoubted ability, on a subject of the very first importance; and I hope with the editor of that review, that a translation of Mr. Say's treatise will meet with sufficient encouragement, to remunerate its publication. Too much publicity cannot be given to works of merit, on any side of the great questions of political economy.

Mr. Ganilh's leading positions are

1st. That the basis of public happiness and prosperity is national wealth.

2dly. That national wealth connects the poor and the rich, ameliorating always the condition of the former, as to their rights, privileges, and enjoyments.

3dly. That national wealth always has followed, and is principally promoted by foreign commerce.

4thly. That there can be no accumulation of wealth in a state merely agricultural, inasmuch as no equivalent can be given in such a state for the surplus produce of agricultural labour.

5thly. That the foreign trade, is greatly more productive of national wealth than the home trade: and therefore governments ought to afford it particular encouragement.

6thly. That Colonies contribute greatly to national wealth.

7thly. That it is the duty of governments, to interfere, and to regulate the course of national industry.

In all these positions I think Mr. Ganilh more or less mistaken. I shall therefore take an opportunity of reviewing Mr. Ganilh's book, and of refuting (if I can) not only these leading features of his system, but many of his other statements of minor importance, connected with his general theory. Probably in the next number. T. C.

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Index to the dissertation on the Iron *manufacture.*

IRON.

This is the most extensive, and by far the most valuable manufacture of this, or indeed of any country: for beside its intrinsic importance, the perfection of almost every other manufacture depends upon that of Iron.

Important as it is, I know of none so long practised and so little understood. Almost all the principal publications relating to it, I have at one time or other had occasion to consult; but little as I have seen of the practice, I am fully persuaded, that no reading will compensate for want of opportunity of observing the actual state of the manufacture leisurely and patiently in all its stages. However, I am certain that it will be a work of utility, to digest and condense the principal facts and observations that I can find registered in the publications relating to this subject. Those who desire more minute information from writers, will have to consult,

The detail of the Swedish practice in folio with many plates by the *Baron Emanuel Swedenborg*. I have not met with this laborious and important work, (which I formerly perused with much interest) in this country. Nor have I found here,

Rinman's Historia ferri; a very good book, which is not yet translated that I know of, at least into English. It is translated into German. This was first published in 1782. 1772 the same author (Sueno Rinman) published his Introduction to the art of improving the manufactory of Iron and Steel. In 1789 his large Dictionary of mining. In 1784 and in 1798 and 1800 he published his System of mechanics with their application to mining in conjunction with Erick Nordwall. These works, of which I have seen none but the Historia ferri, are regarded as stock books on the subject, and ought to be in every

publick library: especially, as even yet in England, their best steel can only be made out of Swedish iron.

In 1783 I translated for my deceased friend Dr. Ch. Taylor, the Dissertation or *Thesis de Analysi Ferri*, of J. Gadolin, published by Bergman, which first gave to the public, accurate experiments on the different products of iron and steel when treated in the moist way.

Horne's essay on iron and steel, 12mo. is a book well spoken of, which I have never seen.

Reaumur's small treatise on the conversion of iron into steel: of which there is an English translation: but the observations and theory, are for the most part superceded by the more accurate knowledge of the present day.

The works I have actually consulted for the present occasion, are

The mineralogical treatise of *Schlutter*, by Hellot, in 3 vols. quarto, of which there are two copies in Philadelphia.

The mineralogical travels of *Mr. Jars*, in 3 vols. quarto.

The series of Essays of *David Mushet, Esq.* of the Clyde iron works.

Bergman's dissertation on the white ores of iron, and the essay *de analysi ferri.*

Tilloch's Philosophical magazine.

The specifications of *Mr. Cort*, and *Mr. John Wilkinson*, in the Repertory of arts, and *Dr. Beddoes's* account of Mr. Cort's process.

The essays of *Dr. Collier* on the steel furnace in the Manchester Transactions: and of *Mr. Varley*, in Dr. Tilloch's Philosophical magazine.

The detached essays on steel in Nicholson's Journal: and

The well-written articles in *Aikins's* Dictionary, and in *Ree's* new Encyclopædia. Giving however my own view of the subject, and adding occasionally my own remarks where I feel myself entitled to offer them.

There are few chemists in this country among manufacturers, and I shall therefore endeavour to make use of such language, that men who are not skilful chemists may understand me, but some technical expressions I must employ. I do not write for professed chemists, or to instruct practical iron masters, or to transform suddenly a person who is ignorant of the subject, into a skilful founder, or forgeman: but to lay together such observations, as may give some connected ideas to those who are not Iron masters, and lead those who are, to reflect on the views which ought to guide every part of their process, as it comes in succession.

Preliminary observations. I have repeatedly met with persons, who think that nothing more is necessary to render a place valuable for iron works than that there should be plenty of iron ore on it. But, beside this (which ought to be at least a 20 years stock,) it is necessary to enquire, whether there be plenty of wood for charcoal, and at what price a permanent and perpetual supply can be obtained—whether there be plenty of water to furnish at all times the necessary force—whether the situation be convenient to a never failing market for the ware when made—whether it be within reach of water carriage—what other works interfere with it—whether lime-stone be handy if it should be necessary as a flux—at what price per ton the ore and the coal can be delivered at the furnace—and what is the quality of the ore itself. For this purpose, it may be well enough, not merely to get the opinion of some skilful iron master or founder in the first instance, but also to get a loop or two, run in a rough way at a bloomery, out of the ore. When all this is satisfactorily ascertained—when the ore bank, and the woodland is purchased—when the water-force for the blast is secured—the capital to build the purchase on a moderate scale, say 30 feet square on the ground plan; to raise the dam, to dig the race, to lay on

the water; to construct the water wheel, the drums, the out-buildings; to erect cottages for the work people; to furnish teams; to lay at the furnace mouth three months supply of coal, and ore, and lime-stone; to make roads; to pay wages and other current expences for six months before any return of capital is made, will require 10,000 dollars to enable the iron master to go on smoothly, and without making sacrifices. A man of experience in the business *may* begin with something less: but the experiment is rendered hazardous, requiring incessant diligence; and many accidents that though not foreseen, ought to be counted upon, may defeat the undertaking: moreover, to every calculation of probable cost, at least ten per cent ought to be added for the article of contingent expences, to which every new undertaking is liable.

It is not common in England to erect iron works without making a bloomery, a slitting mill, and a rolling mill, parts of the establishment. It ought to be so every where, but it is seldom so in this country.

In England very few iron works depend upon a water force: they are worked by steam engines: in this country, steam engines are as yet but little known. The time I hope is fast approaching, especially in the coal districts, when our manufacturers will find the advantage of carrying their power to their works, and not their works to their power.

In England nine tenths of all the iron made, is made by the coak of pitcoal: in this country, as on the continent of Europe, the charcoal of wood is used, almost exclusively. I see the day coming when we also shall be driven to the use of pitcoal, of which there is great abundance in many parts of this country. Hence I shall not think it improper in the course of this dissertation to present the reader with facts relating to this kind of fuel; for I am well persuaded that in a few years they will become useful.

Remarks on Iron Ores, the mode of working them, and their general classification.

The following remarks are from Mr. Mushet, 3 Phil. Mag. 193.

Iron-stones, though commonly denominated ores of clay, contain notwithstanding a variety of mixtures, and may with propriety be divided into the following classes:

1. Iron-stone that has clay for its chief componant earth, and this clay comparatively pure and free from sand.

2. Iron-stone possessing lime for its chief mixture, and this lime also comparatively destitute of sand.

3. Iron-stone that unites clay and lime, containing large proportions of silex; hence, for distinction's sake, these may be denominated siliceous iron-stones. I shall therefore, in naming these varieties, use the following terms as they are arranged in succession. Argillaceous, calcareous, and siliceous iron-stones. None of these earths exist singly with the iron. All iron-stones contain a mixture of the three, in various proportions; from which arise the supposed variety of the qualities of crude iron, which each respective stone is said to contain. There are some, however, which are composed of nearly the same proportions of clay, lime, and silex; and these commonly afford, when compared with themselves, a similar quality of crude iron.

Nature, in the formation of these secondary ores of iron, has invariably impressed characters upon them, easily to be developed: by which means their qualities, and the consequent effects produced in the blast-furnace, may be accurately and distinctly prejudged. The source of this information is, the study of the nature of the united earths; by ascertaining the quantity and proportion of which, we are enabled to pronounce exactly upon the quality of the iron likely to be obtained from the ore. We must not, however, consider these characteristic fea-

tures as a consequence of the metal existing of a variety of qualities; but, *a priori*, we ought to consider, that, as a consequence of the nature and proportions of the mixture, the iron will be called into existence in a state more or less oxygenated or carbonated.

When iron-stones are said to contain *good* or *bad* iron, the expression ought to be understood, which by the bye is seldom the case, only as a comparative assertion, confined to local rules, and judged by certain fixed local standards; into the account of which many things must be taken, which are frequently overlooked. At every iron-work, a certain proportion of fuel, coaks, or wood char, by weight, is understood to be sufficient to smelt, and give principle to a determinate weight and quality of iron-stones combined together, in order that a certain quality of crude iron may be produced. In this case, should a new iron-stone be substituted for one whose quality and effects are already known, and should its application be productive of iron less carbonated than formerly, it would instantly be denominated a *bad* iron-stone, or an iron-stone containing bad iron—an assertion only true comparatively, so far as it would affect the interest of the manufacturer, unless corrected by an addition of fuel, a change of the mixtures of ores, or a varied application of the lime-stone used as a solvent or flux. But this is no proof that the quality of iron, as it exists in the ore, is bad, since a larger proportion of coaks, or a change of mixture, which incurs no additional expence, can correct the evil. It rather furnishes a demonstration that the iron in all ores is the same; but that, in calling it into a metallic form, the quality is affected chiefly by the reduction of those mixtures originally united with it.

As the quality of the fuel is improved in a direct ratio to the quantity of carbon which the coal contains, and its purity, hence arise the great variety of coaks used in smelt-

ing iron-stones; some of which will smelt, and give principle to the iron contained in double the weight of the same ores that others will. From this then may be deduced another proof, that *good* and *bad* iron are terms of comparative meaning only, confined to situation. Let it be conceived that a change of fuel opposite in its quality to that now mentioned was to take place; the same quantity of ore, which with the good coaks would have afforded metal richly carbonated, would now yield its produce in a partial degree, and that highly oxygenated—almost unfit for any purpose. The consequences here entailed are the same, though they may be attributed to different causes; the former as derived from the hostile mixture of the ore, but the latter as arising from a deficiency in the quality of the coaks.

Besides these two leading instruments of alteration in the smelting process, inherent in and derived from the materials, good and bad effects may be produced from an unjust proportion and quality of the lime-stone, which is added, in order that the proper equilibrium may be restored, and the iron properly and beneficially revived.

Taking this then for a general principle, that the crude iron contained in all iron-stones is the same, and that it can be called into existence as a metal of all the various degrees of carbonation, by regulating the proportion of fuel, and of the solvent; I shall proceed to mention those mixtures which I have always observed determine the future quality of the crude iron.

1. Argillaceous iron-stone having fine clay as its chief component earth, lime in the next proportion, and both these nearly destitute of sand; which, when properly torrefied, exhibits fibres on its internal surface, of a brown, dark brown, or claret colour, running either in streaks or radiated, and adhering tenaciously to the tongue, will afford, with a moderate proportion of coaks and lime-stone,

iron of the finest quality, possessing strength conjoined with an intimate degree of fusibility.

2. Calcareous iron-stone, that which contains lime as its principal earthy mixture; holding clay in the next proportion, and both these comparatively unallayed (totally they never are) with sand; which, when regularly torrefied, assumes a variety of shades generally lighter in the colour than the former class; which sometimes, and sometimes not, presents internal fibres, and which adheres less tenaciously to the tongue; always contains iron, which can be revived, richly carbonated with a comparatively small quantity of coaks, and with a trifling addition of lime. Under this class of iron-stones are found those which produce iron of a fusible nature, seldom connected with strength, but valuable for its utility in fine castings, which require ornament more than durability. It is also from this source of mixture that I would trace the red short quality of bar-iron. The nature imposed upon crude iron in the blast-furnace by the developement of its mixtures, most commonly accompanies it through all its subsequent stages of existence as a metal.

3. Those iron-stones whose component parts are nearly an equalised mixture of clay, lime and sand, which torrefy with a slight degree of adhesion to the tongue, assuming a dark-red or brownish colour, void of internal fibre, always afford, with the local proportion of fuel, iron of an intermediate quality for fusibility and softness, but generally possessing strength in an eminent degree. Such iron is excellently adapted for the manufacture of great guns, mortars, and the large species of machinery. Its application to the purpose of bar-iron making, would also be attended with the most beneficial effects, possessing neither the extreme of fusibility nor of infusibility: it would greatly prevent, in the manufacturing, a tendency, which iron possessed of these extremes has, to become red or cold short.

4. Iron-stones which unite a large proportion of sand with sparing proportions of clay and lime, which, upon being slightly exposed to heat, exhibit masses of semivitrification, neither obedient to the magnet, nor adhesive to the tongue, having a refractory disposition to part, and possessing a dark-blue or black colour, always afford, with the usual proportion of fuel, crude iron of the worst quality, either as to strength or fusibility. Such metal is commonly highly oxyginated, and brittle; incapable of being used alone for any melting purpose; and, when applied to the use of the forge, affords malleable iron, which possesses the cold short quality.

These are the four principal classes under which I have arranged our iron-stones, with regard to their tendency to afford their iron carbonated, possessing strength, or otherwise, when smelted in the blast-furnace with a determinate quantity of fuel. As this classification is exactly analogous to the results obtained in the large way, it may serve as a ground-work to those who may wish to attain a practical knowledge of these ores, so far as it relates to their manufacture.

It is however easy to counteract the natural tendency which every iron-stone has in this case, to afford its iron of a certain quality, and to make each of them yield crude iron of all the different degrees of fusibility and strength. Is it not obvious, that since the qualities of crude iron depend upon the mixtures and their kinds composing the stones, that if nature be assisted by adding or subtracting from them in the blast-furnace, every quality of crude iron may be produced from the same iron-stone? I have seen most of these results determined in the large way, and the whole of them beautifully confirmed in the assay-furnace.

It remains with the present manufacturer to consider whether it will be more his interest to reject such iron-stones as are of difficult carbonation, or to apply the neces-

sary additional proportions of fuel, capable of correcting the quality of silicious iron-stones. Not so, however, to those who may at some future period succeed him; necessity, at all times ingenious, assisted by the increasing light which science daily sheds over our manufactures, will devise the means of calling into profitable existence the metal contained in all those ores which may have fallen into disrepute in the present day, or from which at this time it is thought impracticable to extract metal in the large way.

The usual criterions by which iron-stone is judged, whether it be sufficiently rich in iron for the purpose of smelting, are the following:

1. The degree of tenacity with which it adheres to the tongue after torrefaction; 2. Its colour: 3. The obedience to the magnet when pulverised: 4. By depriving of its iron a given weight of the ore, in contact with charcoal and fusible earths in the assay-furnace.

The first and third of these methods are liable to great error. The adhesion to the tongue will be more in proportion to the quantity of its clay and its kind contained in the stone, than to its real contents in iron. Iron-stone may also be torrefied in such a manner as to deprive its internal surface of this property; as it is only peculiar to the stone at a certain stage of torrefaction.

Those iron-stones with which Britain so much abounds, and which are now universally used for the production of cast-iron with pit-coal, are commonly found in horizontal strata, subject to the same acclivity and declivity with the other stratified substances under the surface; their inclination from the horizon varying according to the nature of the ground, and the disposition of the imbedding and incumbent strata. Such variety is exhibited, that strata of iron-stone are found descending 1 yard in 24, 1 in 12, 1 in 8, and sometimes 1 in 4. Where the accli-

vity or declivity of the metals is small, the most extensive and regular fields of iron-stone are to be found, and *vice versa* where the metals lay more on edge.

Iron-stones are generally found imbedded in schistous clay more or less compact, but which moulders away when exposed to air. They assume two different forms: regular connected strata called *bands*, and strata of detached stone found in distinct masses, from the size of the smallest bullet to the weight of several hundred pounds. Those of the small and middling sizes, and which generally wear a flat ovular form, are called *ball-stones*: those of greater weights are by the workmen denominated *lunkers*.

Both these species of iron-stone frequently accompany coal and limestone. In the former case they are commonly incumbent, and found almost in immediate contact with the coal: little extra labour is therefore requisite to bring down the stone; and the double purpose of obtaining both materials is thus advantageously answered.

When iron-stone in bands accompanies limestone, it is most commonly of an inferior quality. Its component parts are chiefly calcareous, and the quantity of iron it contains is small. Ball iron-stones found near to lime are of a much superior quality, and for the most part contain a considerable proportion of iron.

Thus stratified in the vicinity of lime, many iron-stones are found with various impressions of marine remains; and not unfrequently compact and entire shells, univalve and bivalve, are found in the heart of the band. It is however still more difficult to conceive how shells could be deposited, distant from lime, imbedded in iron-stone, incumbent on coal, at the great depth of 80 yards from the surface. In our neighbourhood, at this depth, a small band of iron-stone is found completely covered and interspersed with distinct muscles of an ordinary size.

The Rottenburn iron-stone of Lancashire, consists of a band and an accompanying ball. The former abounds with fine specimens of the ramification of trees, shrubs, &c. In the process of decay, and the substitution of mineral in place of vegetable substance, the more ligneous parts and the bark are distinctly preserved from the heart of the shoot.

This iron-stone contains 37lb. in 100 extremely susceptible of receiving the carbonaceous principle.

Another variety of iron-stone, which we have in this country, and which will be deemed no less curious by the mineralogist, affords maltha, bitumen, mineral pitch, &c. This combustible is found in the heart of large flat rounded balls of iron-stone, occupying a number of interstices, and resembling a cement for the frittered pieces of stone. The distillation of 437 grains afforded me a rough light charcoal, which weighed only 49 grains; this, when exposed to fire in contact with air, burnt without a residue; hence I conclude it to be pure carborn. This iron-stone in the assay-furnace yields 36 pounds of iron in 100.

All these strata of iron-stone bear the most evident marks of the agency of water.

Working of Iron-stone.

When iron-stone is found near the surface, it is only necessary to unbare the soil and the super-incumbent earths: the stone then presents itself like a pavement more or less inclined, and is easily raised by the application of wedges, bars, &c. &c. But as all secondary strata descend, according to the declivity imposed upon them by nature in their formation, it is obvious that, in proportion as the excavation extends at right angles to the line of level, the stone becomes gradually buried under an accumulating depth of earth, till such time as the expence of throwing this off exceeds either the value of the stone, or

the expence at which it could be procured by a different mode of operation. It therefore becomes necessary to make perforations by means of horizontal galleries, extended under the soil, so as to fall in with the declivity of the strata: these catch the inclining stone for a stretch of 100 to 240 yards, according to the existent circumstances of the mine.

These galleries are in Scotland called the barrow roads. Whenever the miner has arrived at the extremity of his working, he turns round and commences an excavation on his right and left hand, proportioned to the rise and dip of the stone, to the extent of several yards on each; the accompanying shist and rubbish are packed into the vacuity behind him: should there remain any superfluity unpacked, it is wheeled to the mouth of the gallery along with the iron-stone. In this manner the miner returns, and brings along with him the whole iron-stone contained in 100 to 240 yards in length, and in 20 to 30 yards in width. The height of the gallery is commonly so small, that the miner is obliged to perform his work upon his side; the wheelers are likewise obliged to push the barrow on all fours. This species of working is called under cover; and the attainment of a band of good iron-stone, though only four inches thick, will sufficiently defray the expence of the operation. It is here also obvious, that this operation can only be carried a certain length in the same gallery, till such time as the expence of wheeling out the stone must exceed the value of that share of labour generally appropriated to it. A more economical method is therefore indispensibly requisite. This is effected by sinking a pit 160 to 200 yards farther on the same line of level. When the iron-stone is found, the miner sets off another gallery, or barrow road, towards his former working, and continues till he meets the termination of his *old waste:* as formerly, he now begins his retreat, and carries

with him a similar portion of iron-stone from each side of the gallery. The quantity of iron-stone by weight obtained from such a *working*, depends entirely upon its extent and the thickness of the band. A square yard of iron-stone containing 9 cubical feet, as it lays stratified, will weigh from 1850 to 1900 pounds weight. The other side of the pit is next perforated, and the same operation completed. When the iron-stone is thus exhausted, another pit, sunk at a similar distance from the termination of the second gallery in the first, opens up a new field of supply. In this manner iron-stone is continued to be raised, till such time as the *field* is totally exhausted.

These extensive excavations commonly collect a considerable quantity of water, which would soon impede the progress of the workmen: various means have been contrived to remove this consequent obstruction. These have chiefly consisted in running a counter gallery as far to the declivity of the *metals* as possible, and of passing the water into it by means of filtration, or communications betwixt gallery and gallery. Where a sufficient quantity of running water presents itself, water-wheels have been applied, to extract the water from one general reservoir by means of pumps.

Strata of iron-stone are from 1-2 an inch to 12 inches in thickness. Those of 3, 4, 5 and 6 inches are most commonly met with; they are also reckoned to contain a quantity and quality of iron superior to larger bands. Ball and lunker iron-stone, however large, contain always a superior quantity of iron, and are easier reduced in the blast-furnace. *(Mushet.)*

On Iron Ores particularly,

1st. As to the state of the iron as it is contained in the ore.

2dly. As to the quantity of the iron contained in the ore.

3dly. As to the kinds and proportions of earths, with which the iron ore is mixed.

As to the *state* of the iron as it is contained in the ore.

Iron ores contain the iron either combined with sulphur: or with sulphur and arsenic; or mixed with copper ore; or with manganese: or in the state of an ochre or oxyde: or in the state of what the chemists call an oxydule, frequently magnetic and more approaching to the metallic state: or combined with acids, and forming saline substances, such as green vitriol, &c.

The sulphuretted ores, are usually called Pyrites; they are often of a metallic gold colour, hard, and brittle, giving fire with steel. These are seldom worked, unless to collect the sulphur, or to make green vitriol. But several ores worth working, contain also sulphur, or arsenic, or both. This can be ascertained by reducing them to powder, and exposing them to a cherry-red heat, when the smell will generally detect both the sulphur and the arsenic. The fumes of the latter also, will whiten copper.

Ores much mixed with copper, can seldom be worked with profit in a furnace. The mixed metal is brittle and bad. Some ores at Cornwall furnace, (Mr. Coleman's) are of this kind, and are not worked.

Ores are very often mixed with a notable proportion of manganese, as I have seen them at the Dunham works, that formerly belonged to Jos. Galloway. This mixture is a detriment, though of late it has been proposed to give the properties of steel to iron by means of manganese, in a large way. These ores are blackish, and give a full green slag with common white glass and potash as a flux. Nickel, Crome, and Phosphorus are also frequently combined with iron, but it requires much chemical skill to separate them accurately. In a large way, they must be separated in the bloomery and by the hammer.

The oxydes of iron, and the iron combined with carbo-

nic acid, are usually worked to profit, as in the common mountain iron-stone, and the bog-ores.

The salts of iron (unless the carbonat of iron be so called) are never smelted for the purpose of obtaining metal.

Whether an ore be magnetic or not, is no criterion whether it be worth working or not. This quality has influence only on the quantity of carbonaceous matter necessary to metallize the iron.

As to the *quantity* of iron contained in an ore. Whether it be worth working or no, depends less upon this criterion, than upon the circumstances, whether it can be easily gotten, and easily and cheaply fixed. The shining sulphureous pyrites often contains more than fifty per cent of metal, and is not worth working: the poor ore of Staffordshire, in England, that does not yield more than from 16 to 20 per cent, is a profitable concern, because it is easily reduced to a metalline state, and when so reduced is of good quality.

As to the kinds and proportions of *earths* with which the stone is mixed. Let it be remembered, that,

The earth that gives the character to common clay, and to clay stones is called *argillaceous* earth. The earth that gives the character to limestone, is called *calcareous* earth. The earth that gives the character, to quartz, flint, whether transparent or opaque, to flinty sandstone and stones of that hard nature, which scratch glass, and give fire with steel, is called *siliceous* earth. The earth that gives the character to soapstone, and stones of that class, that appear soft and greasy to the touch, is called *magnesian* earth. Iron-stones contain the latter in so small proportion for the most part, that its effects need not be noticed: but the rest are of great importance to be known; for whether any limestone ought to be added as a flux, or in what proportion, depends on the kind and quantity of the earth, that envelopes the particles of iron.

Before I class iron ores in this respect, I would observe, that it is necessary to bring the iron into a metalline state which is done by charcoal and heat. Also, that when brought into a metalline state, it will not fall down and unite in one mass, but be enveloped in separate particles among the coals, unless the coals and the earths of the stone, are brought into fusion, and made into a glass so thin that the particles of metal by their superior weight, will fall through them. This is done by knowing in what way the earths can be so mixed, as to be brought into thin fusion, by the usual fire of a furnace.

On the fluxes of Iron ores.

The principles on which all earthy fluxes depend, is, that no earth is fusible alone—that argillaceous and siliceous earths together are infusible—that argillaceous and magnesian earths together are infusible—that silicious earths and magnesian earths together are infusible—but that when lime or limestone (calcareous earth) is added to any mixture of the other two, they will run into a glass, which will be thin and fluid with the same application of heat, in proportion to the judicious mixture of the several earths. M. D'Arcet, a French chemist, made this experiment: He put into one crucible a round marble of clay, into another a ball of the same size of quartzose or silicious sandstone, into another, a ball of the same size of chalk; and exposed them to a violent heat in the same furnace for the same length of time. They were all uncharged, except where the chalk ball had touched the crucible; in that place, there was the appearance of fusion. He put all three balls together, first reducing them to powder and mixing them. In a short time the same furnace melted them into a transparent glass.

Moreover the experiments of Mr. Kirwan have ascertained

That argillaceous and siliceous earths—argillaceous and magnesian earths—siliceous and magnesian earths, would not melt in whatever proportions they were mixed. That siliceous and calcareous earths—argillaceous and calcareous earths, by very strong heat might be vitrified, but not into a perfect and thin glass.

That when the earths are calcareous, argillaceous and magnesian, it requires that the lime should be in a double portion to make a glass.

That no glass can be produced if the clay-earth or the magnesian earth predominate.

That calcareous earth, argillaceous earth, and siliceous earth—or, calcareous earth, magnesian earth, and siliceous earth—can be brought into perfect fusion if the calcareous earth somewhat predominate. And that by means of a strong heat, a perfect glass may be produced by siliceous, argillaceous and magnesian earths alone, without lime: and that this is the only combination he tried, in which limestone earth was not absolutely necessary in the mixture, to make glass.

He further ascertained, that all the metallic oxyds, and of course that of iron, assisted in producing fusion: also, that common clay contains one half or more of its weight usually of sand, intimately mixed.

Hence limestone earth, or calcareous earth, may be regarded as the substance most fit in an economical point of view to bring other earths into thin fusion; for which purpose it should be in the proportion of 1 1-2 or nearly 2 to 1 of that earth which predominates in the iron-stone.

Hence, if clay predominate in the iron-stone, (or earth of which pure clay is the basis) the flux is limestone: and on the contrary if the iron be mixed with limestone, the proper flux is not limestone, but clay.

Also, that herein consists much of the practical knowledge of assorting ores, namely to mix together such ores,

as may contribute to flux each other, being with difficulty fluxed alone.

Hence also, appears the necessity of this knowledge, in order to save coals, to save time, and to prevent the iron from being entangled and enveloped in a thick unyielding refractory slag, or scoria.

Hence also, the necessity of beginning your operations, by trying what earth, and in what proportions your ore contains: that is, to analyse your ore.

Of course, my next section will treat of

The Analysis of Iron ores. Chemists usually agree that the constituent parts of an ore, cannot be accurately known unless by analysing it in the moist way; that is, by solution in acids or alkalies, and by precipitating the substances dissolved, by means of what are called re-agents. I am of this opinion too. But such an accurate analysis is not practically necessary, nor is it practically true: for in the course of operations of a large manufacture, it is not to be expected that the iron yielded by a thousand ton of ore, will correspond with the result of the analysis of an ounce.

The best mode in my opinion is to proceed in the small way, pretty nearly upon the same plan that you proceed in the large way.

The two objects then are, first, to find out what proportion of flux your ore will require, and of what kind, so as to be fused most compleatly at the slightest expence. 2dly. Find out how much iron you can procure by means of fire and fluxes, out of a given weight of ore.

If you have not the means of a good wind furnace, you must go to a blacksmith's shop for the purpose. But every establishment of iron works, ought to have an assay furnace, of which the surface, should be 3 feet from the ground: the furnace hole 20 inches deep, 14 inches wide at the bottom, 12 inches wide at the top: the cruci-

ble-stand, should be 6 inches high from the centre of the grate, wherein there should be an even platform of 4 inches diameter to receive it and enable it to stand steady. At 6 inches from the top of the furnace there should be an horizontal side flue of 6 inches by 6 inches, and 9 inches long, with one end opening into the furnace, and the other into the upright chimney. The chimney should be 6 inches by 9 inches or thereabout, and not less than 20 feet high. The cover should be of fire clay mixed with burnt brick, well beaten, and burnt, and enclosed in a wrought iron frame with a handle to lift it on and off by. This cover should fit accurately to the surface of the furnace, and be at least 14 inches square. With such a furnace, heat enough may be given for most experiments, especially if about 1-2 of the coak of pitcoal be mixed with the charcoal; neither of these ought to be used in lumps bigger than a small egg. The inside of the furnace ought to be lined with refractory or infusible fire clay over fire brick; or else with a mortar of pounded clay mixed with pounded soap stone. Mushet's assay furnace with a pyrometor measuring the degrees of heat, is to be found in 4 Philos. Mag. 255. but I like my own as well. The powerful three-blast assay furnace of the French school of mines, is delineated in 14 Philos. Mag. 69. It is worked by 3 equidistant tweers. It should be remembered that both in England and France, the men of science in their laboratory, and the men of experience in the iron manufacture, have gradually encreased the admission of air into their furnaces, and divided the quantity between two tweers.

The first process I would advise should be to ascertain whether there be any limestone in your ore, and how much. For which purpose

Take 400 grains of the ore in fine powder, from among the powder of at least half a dozen fair specimens of the mine.

Pour on it in a glass tumbler half an ounce by measure (by means of the common graduated measuring glasses used by apothecaries and chemists) of common spirit of salt, to which add twice as much water. Expose it to a heat nearly boiling for half an hour. If there be no effervescence, there is probably no limestone. If there be, continue to add by small degrees, spirit of salt and water, till all effervescence is fairly over. Let it stand 3 or 4 hours. Then add half a pint of water, stir it well, and filter the whole through (unsized) filtering paper. Wash what remains on the filter, with half a pint more of water, and add the filtered liquors together. This will dissolve all the limestone earth, and perhaps some of the ore, and a small portion of the argillaceous earth, but these last are of no consequence.

Then add to the filtered solutions, two drams by measure of oil of vitriol, which will throw down the limestone earth in a thick sediment in the form of gypsum or sulphat of lime. Let it rest, and add a few drops more of the oil of vitriol, until no fresh sediment any longer appears. Pour off the supernatant clear liquor: add half a pint of hot water, and filter: wash the filter with two more half pints of hot water, until the liquor that passes through, is no longer sensibly acid. Let the filter remain to drain for 24 hours. Scrape off all the sediment, put it in a cup or a saucer to dry for at least six hours on a common iron stove, or 120° of Fahr. let it so remain till dry and powdery to the touch; when 150 grains will designate 100 grains of limestone. Or else (which is more accurate) expose it for half an hour in a crucible to a red heat, when 135 grains will designate 100 grains of limestone.

The limestone may be generally, ascertained also, by means of the air it contains, but it requires some little knowledge of pneumatic chemistry. Thus, weigh a common pint decanter, that will hold a full pint. Balance it in the scales. Put into it, 1lb. avordupois weight of water,

at the temperature of 60 of Fahrenheit's thermometer. Now as 44 grains of chalk will yield air, equal to that bulk of water, one pint of air will designate 44 grains of pure limestone. This can be done by fixing a tube of tin, or copper, or glass, bent like the letter S into a cork. Insert the cork in the bottle or vial which contains your mixture of spirit of salt and water with the ore to be tried. Invert the pint decanter full of water in water, and let the air displace the water of the inverted decanter.

Having thus ascertained the quantity of limestone if any, you will have a guide how much to add, when you know the proportion already contained in the ore. If the ore be, as it often is, an argillaceous ore, which can be told by putting your tongue to it, which will adhere; or by the earthy smell perceived on breathing on it, it will require more limestone in proportion to the clay. Calcareous ores and siliceous ores, do not emit an earthy smell or adhere sensibly to the tongue.

If your ore be a calcareous ore, that is, inveloped in limestone, it would be absurd to use a limestone flux; your flux should be half its weight of clay. If it be a siliceous ore it will require both limestone and clay. Nor is it the *quantity* of iron alone, that depends upon the due mixture of the earths which are to form the flux: the *quality* and appearance of the iron produced, equally depend upon the same circumstance: and it may be safely taken for granted, that when an ore is well deprived by roasting of its sulphur or its arsenic, if there be any, and when the due proportions of coal for heating and metallizing, and of earths as a flux are known by well ascertaining the component parts of the ore, every ore may be made to furnish the same kind of iron.

Directions for assaying ores in the small way, by the same process that is employed in the large way, are given in the following papers of a practical and experienced iron

master, which are better than any thing of the kind I have seen elsewhere, though intermixed with some speculation.

On the Assaying of Iron Ores and Iron Stones by Fusion. By Mr. DAVID MUSHET, *of the Clyde Iron Works.* 4 *Phil. Mag.* 178.

In our manufactories, the just combination of art with science is what we can seldom boast; in authors, the same happy union of theory and practice is also markedly deficient; and we have constantly to regret, that the want of liberality in the individuals of the one class, and opportunity in that of the other, prevent us from feeling the happy effects of this so much desired union.

The process of depriving ores of their metal by fusion in the assay-furnace, and that part particularly relating to iron, which I mean to make the principal subject of this paper, lead me more immediately to make these observations. With the manufacturer, in general, the uses and propriety of the assay-furnace are seldom admitted, or, at best are restricted to such narrow limits as to be only capable of ascertaining the quantity of iron contained in ore or iron-stone. The chemist, on the other hand intent only upon effecting his operation, and of giving accuracy to the result, confines his observations to a certain chain of science, and seldom or never considers manufactures as the ultimate and happy end towards which his labours should be directed.

With whatever deference and respect we look up to the names of men celebrated for their indefatigable zeal and industry in the cause of science, and with whatever satisfaction we rest upon the result of their labours as to truth; yet, in general, the practical man feels dissatisfied with the manner in which those subjects are treated which come more immediately under his own observation.

It is I fear with some truth that this charge is brought against that part of the arts relative to the assaying of iron ores. We never find, in the works of those whose attention has been directed to this subject, that the least connected idea ever exists betwixt the assay and the blast-furnace, or that the agents used for reduction in the laboratory, can in general be applied to works in the large way. A total silence prevails amongst authors of this class, as to the various qualities of crude iron which certain ores and certain combinations of fluxes produce: all ores, however various, are reduced to the same complex treatment, and the operation itself measured by minutes, as if the fusibility of all the widely differently-combined ores was the same.

The celebrated Bergman even, has a degree of complexity in his receipts for the assaying of iron ores, that seems unworthy of the simple elements of science. The following one in particular seems to possess an air of incongruity even in the proportions, only equalled by the oddity of the assemblage of mixtures brought forward:

"100 Grains of the roasted ore, two parts of the black "flux, (equal parts of borax and nitre,) one part of tartar, "one of sal-ammoniac, one of sandever, half of (again) "borax, half of glass, one-fourth of *clean soot*, one-fourth "of charcoal; the whole to be covered with common salt." This motly association of earths, alkalies, and salts, is recommended as the best flux for ALL iron ores. The author however shews, that the advantages which it possesses are not complete, from the great caution prescribed in the mode of conveying the necessary degree of heat; and the perfection of the operation is rendered altogether doubtful by the consequences which the oversight of a *few minutes* may occasion.

It cannot be well reconciled to our ideas of advancement in any art, that we have not yet discovered a method

of operation more perfect than that, wherein a few minutes lost or gained (which error will more likely take place from the inequality of heat, than the reckoning of time,) make a variation from truth equal to 1-5th or 1-6th of the whole. The manufacturer would be in a lamentable predicament were he thus circumstanced, and obliged, by some means or other, to take the crude iron from the blast-furnace immediately upon being separated from the ores, lest a considerable portion of it should totally disappear. If the degree of heat produced from a smith's forge was at all times the same, though supplied with fuel of various natures, and under different changes of temperature, then it is most probable that, by reckoning Bergman's time to a minute, a button of iron, accurate in its results, might be obtained from *some* ores by the flux he has directed to be used. But I cannot conceive that this should be an universal consequence: far less can I comprehend, after a just separation has been effected, that five minutes will destroy 1-10th of the produce of metal, while the incumbent fluid protects the surface of the metallic button from the action of the atmosphere.

It is not, however, my province to enter into a minute examination of the products obtained from the use of such vitreous fluxes, which are always productive of the most oxygenated state of crude iron; and the accuracy of whose results, under a state of such high oxygenation, are always to be suspected. I have frequently proved that, in using them, the affinity of the metal was so great to oxygen, that a slight derangement of the crucible, which had thrown the vitrified fluid from any point of the surface, was immediately attended by a rapid deflagration, and a considerable portion of the iron oxydated.

I shall chiefly confine myself to a communication of those facts, which I have repeatedly confirmed, with a view of extending my results and observations to a more

extensive scale. I have constantly considered the assay-furnace as capable of affording conclusions applicable to the operations of the smelting-furnace, and that change or innovation should always have the concurring testimony of truth to back them, though, on a small scale, before they be risqued on one more momentous or extensive. Influenced by such motives, I early rejected, as totally inapplicable to the scale of manufacture, the numerous tribe of salts, alkalies, and earths: these, in the application, are subject to no rule, nor guided by any immediate object of general utility, but are as arbitrary as their authors are numerous. On the contrary, I have directed my endeavours to the use of such agents as effect separation upon the large scale, and have been fortunate to find that the same solvents, when properly applied, are productive of the most perfect and finished results. By the simple application of lime or chalk, in various proportions, as a calcareous earth, and common bottle glass, in the place of silex, to constitute fusibility, I have been able to produce in the assay-furnace, all the various qualities of crude iron, as to strength and fusibility. In no case has the result of any assay been considered perfect, unless the vitrid mass found upon the surface of the metallic button exhibited a degree of transparency and purity of colour little inferior to flint glass, or slightly darkened by a faint shade of azure. In such vitrifications, purity of colour is the surest proof of the non-existence of iron in the state of a fused oxyde: the same degree of pellucidity renders it easy to detect the smallest globule of metal which by chance may have been suspended during fusion. In all experiments where a just association of mixtures has been present to produce this peculiar scoria, the quality of the iron will be found richly carbonated, and the button possessing a smooth, silvery, greasy-feel surface. On the other hand, experience has repeatedly shewn, that when the scoria ob-

tained in assaying approached not to the colour and purity of fine glass, there remained a portion of the iron still unrevived, in the state of a fused ozyde, conveying colour and opacity to the mass; that at certain degrees of colour, certain degrees of opacity existed, and proportionate quantities of the metal remained diffused in the scoria. When the colour of this was green, the quantity of metal united was small; but as the green deepened, and became associated with light browns, the quantity of unrevived iron was greater, and became much increased as the scoria assumed darker browns, or became totally black: in such instances I have found it contain, upon being re-assayed, 12 *per cent.* The assaying of iron ores is susceptible of another extreme, by which experiment is equally clogged, and wherein it is very difficult to obtain an accurate result. In this case no perfect button of metal is found, but the portion of iron which the ore contained is in a vast variety of various sized globules of the richest crude iron, interspersed in, or covering the surface of a semi-vitrified opaque mass of scoria, of a greyish-blue, mottled, or whitish colour. The causes of which, and their strict analogy to similar results in the blast-furnace, shall be my chief object to explain.

In a former paper I mentioned, that if iron-stones were smelted without the addition of any other substance, the product in iron would be proportioned to the quantity of lime contained in the respective classes. We shall see from the following experiments how far this is confirmed by means of the assay-furnace, and furnish to ourselves one important lesson, how far the various mixtures of ores affect the operation of smelting?

1st, Into a crucible, with a well-fitted cover, I introduced 875 grains of a pulverised *siliceous* iron-stone in its raw state, and applied such degree of heat as is usually given in such operations. In twelve minutes I found

that the iron-stone was in perfect fusion, much agitated, and emitting large bubbles of ignited gas of a fiery colour. In forty minutes the crucible was withdrawn; the surface of the vitrified fluid still continued to boil, and emit bubbles of air, though in much less quantity. In this state I introduced a small rod through the scoria, and discoverd the surface of a button of metal. The moment it came into contact with atmospheric air, a beautiful combustion took place; the metal rose in a spiral form to supply the rapid inflammation, and continued till the scoria (still in fusion) closed over the surface of the button. When cold, I found a perfect formed button of extremely oxygenated crude iron, which weighed 219 grains; a produce equal to 25·1 *per cent.* from the raw iron-stone. The scoria obtained was of a shining black colour, firm and ponderous, and weighed 402 grains; so that the loss in volatile matter was 254 grains, equal to 29 *per cent.*

Although this iron-stone was siliceous, yet I am convinced the loss of volatile matter would have been greater, had not nearly one-half of the whole contents of iron remained in the scoria, united with oxygen, at the rate of 35 *per cent.* I found the produce of the metallic button thus obtained white as silver, and presenting imperfect radii; the surface was considerably oxydated, especially where the combustion had taken effect.

2d, I subjected to a similar treatment 875 grains of an *argillaceous* iron-stone, which contained a usual proportion of lime; the fusion of this powder was more difficult than that of the former, though the phenomena exhibited by both during reduction were alike. The crucible was withdrawn from the furnace in forty minutes after introduction, and the surface of the button exposed to combustion as before. The deflagration differed little in point of appearance from that effected with the siliceous iron-stone; the button of crude iron was found oxygenated,

and weighed 249 grains; a produce in iron from the raw stone = 28.5 *per cent.*: the vitrid mass was found to weigh 354 grains; the loss of volatile mixtures was therefore 272 grains, or 31 *per cent.* The fracture of the regulus now obtained was still white, though not allied to any degree of crystallisation, and its surface smoother and less oxydated. The glass produced in this experiment was of a deep brown shining colour, in many places porous, and enriched with fine tints of colouring.

3d, The same experiment was repeated upon 875 grains of a fine *calcareous** iron-stone. The fusion of this required a violent heat of seventeen minutes, during which time the disengagement of a gaseous substance was most evident; in other respects it exhibited the same features, when in fusion, as the two former: the degree and length of heat conveyed was nearly the same; and the result obtained was a button of carby-oxygenated crude iron weighing 261 grains; a produce in iron equal to 30 *per cent.* from the raw iron-stone; fused earths, now reduced

* I omitted to mention (p. 37) another method of ascertaining the quantity of calcareous or limestone earth in an ore. Pure limestone contains 44 parts in 100 by weight of air (carbonic acid gas). Take a Florence flask, or the round bottom of a Florence flask, put it on one side of a pair of scales; pour into it one dram by measure or 100 grains by weight of spirit of salt, and as much water. Put weight in the other scale to balance this. Then pour into the acid liquor your ore in powder, and let it remain for an hour. Whatever limestone it contains will be dissolved, and the quantity can be told from the weight lost: suppose the loss 10 grs.: then as 44 is to 100, so is 10 to the limestone contained in the ore. This will be accurate wherever the iron in the ore is not in a metallic state; if it be, air will be given by the iron, which a chemist can separate by means of lime water. But few ores will be liable to this uncertainty.

Oxyd, *Oxydation*, metal combined with xoygen or pure air, which must be separated from it by means of carbon or charcoal.

Carbonated, *carbonation*, the uniting pure charcoal to an ore, which converts it into a metal. T. C.

to an opaque brown glass streaked with white, 294 grains: loss in volatile mixtures 320 grains, or 36.5 *per cent.*

The metallic button produced in this operation had a smooth crystallised surface; and, when in fusion, combined less readily with oxygen offered by the contact of atmospheric air, than did the former two. The fracture was light grey, with a regular distinct grain; the mass of fused earths were disposed after the manner of a crystallisation, in radii, shooting from the circumference of a minute circle to the extremity of one larger.

From these experiments it is obvious that reguli of crude iron may be obtained from the different classes of iron-stones, of a respectable produce, without any addition whatever; and that the tendency which these have to part with their iron is in the exact ratio of the quantity of lime present. The following statement exhibits the difference betwixt the real and partial assay of the foregoing iron-stones.

The siliceous iron-stone properly assayed, yielded 34.5 *per cent.* but by fusion *per se** only 25; leaving in the latter method 9.5 mixed with the scoria. Argillaceous stone, properly assayed, gave 35.6, by fusion *per se* 28.5; leaving 7.1 mixed with the scoria. Calcareous iron-stone, properly assayed, yielded 33.7, by fusion *per se* 30; which left 3.7 mixed with the scoria.

One reason may be advanced why the iron produced from the calcareous stone was so much more in proportion than the other two classes: both the siliceous and argillaceous buttons, when deprived of their scoria, decomposed atmospheric air so rapidly as to suffer a little, in point of real metal, from the combination of oxygen. It was otherwise, however, when the surface of the calcareous button was exposed: the affinity of the oxygen to the metal being less than to the carbon united with it, carbonic acid was formed. A review of these experiments leads to

* By itself: without addition.

another conclusion, that without the presence of carbon, either in chemical union in the ore, or attracted from the ignited gas by the particles of metal, crude iron will not separate from the ore or stone; and that, in proportion as the metal is exposed to inhale this principle, its produce is increased and its quality improved.

It will further appear obvious, from the various natures of scoriæ which the different iron-stones afford when fused *per se*, that there exists a want of mixture in most of them to form, when fused, a fluid so sufficiently divided that no portion of iron may be retained, either in a metallic state, or in that of an oxyde. This deficiency of mixture is greatest in the siliceous iron-stones, less in the argillaceous, and least of all in the calcareous. The principle, therefore, I proceeded upon was, to ascertain what proportion of additional mixture, and of what nature, was necessary to give the proper equilibrium to form a transparent slag or scoria. When silex predominated, it was found that a major proportion of calcareous earth, in the solvent or flux, supplied the natural deficiency; and that the whole contents in iron were justly revived, and fully saturated with carbon: when at any time it was wished to revive the metal, contained in such ores, possessing strength with carbonation, I found that this could be easily effected, in all proportions, by the addition of calcareous earth with a mixture of pure clay. In short, in every experiment I have made with ores, the various natures of limestones, or chalk, with certain proportions of bottle glass, have been found capable of reviving the iron contained in all the ores which have come under my knowledge, and of conferring upon their respective products every degree of strength and fusibility *. In order to form an accurate

* Although I have frequently had occasion to mention the combination of clay with iron-stone, as the mixture which in fusion conveyed strength to the metal, yet I have not ventured a conjecture

judgment of the tendency which individual ores have to afford their metal carbonated, possessing strength, or otherwise, a flux of a medium proportion of calcareous earth and glass is determined upon; such as, with an iron-stone of that genus, would afford super-carbonated crude iron. Let the button of iron so obtained be the standard whereby to judge of succeeding results; and let all the ores belonging to the same mine, or used at the same work, be compared with it: these will be found, according to their mixtures, possessing different degrees of carbonation; some of them white in the fracture, and others again as richly carbonated as the standard regulus; their degrees of strength also approaching or receding from the standard as they approximate or vary from the nature and proportion of its original mixture.

To complete such an undertaking with accuracy, requires a minute knowledge of the operations of the assay-furnace, and the degree of heat from time to time excited: the quantity of ore in such a chain of experiments should

how far and in what manner the mechanical structure of the metal is altered when additional strength is thus obtained. It will be a difficult matter to decide, whether it is derived from the natural infusibility of the clay, by preventing separation for a longer time, and new modifying the structure of the particles of metal; or whether the acquired strength is entirely owing to the moleculæ of the metal becoming more flattened and tenacious by a varied stage of crystallisation. Most probably it is owing to both causes, and that the former is productive of the latter; the one the cause, and the other the effect accounted for.

We find, that from siliceous iron-stone, which is fused with the greatest facility, iron is obtained uncommonly white and brittle; and again, from pure calcareous iron-stones, which are still more difficult to reduce than the other two classes, we find an opposite extreme of brittleness, arising from an extra combination of carbon, which destroys the continuity of the particles to each other. Clay still holds the medium; and its addition alone restores a just equilibrium, not of strength only, but of fusibility. Mushet.

be at all times the same, and the requisite heat conveyed and completed at similar stages of fusion and of separation. Strict accuracy of result, as to the quantity of metal, will not always be obtained; but a very comprehensive knowledge will be formed of the nature of the earthy mixtures, and the strength and fusibility of the metal. Once in the possession of these, it will be no difficult matter to superadd a portion of earths requisite for perfect reduction. In two simple experiments, therefore, not only the real quantity of metal contained in the ore is obtained, but its presumptive strength and fusibility developed in a great measure prior to its application to the purposes of the blast-furnace." * * * *

'It will easily be conceived, from the mode of operation which I have adopted, that, in order to procure accurate results, the proportion of flux must be varied according to the mixtures in the iron-stones or ores; and that no universal solvent can be used as capable of assaying *all* ores.

As the gradation of mixtures in the ores is almost imperceptible, there are, in fact, no fixed limits by which Nature has distinguished the various classes: we find all the varieties diminishing their predominant earth, and assuming, in equal proportions, those of each other, thus constituting the class of equalised mixtures; yet, here, the variety of combination ceases not, the predominating earth gradually becomes the minor part of the mixture, and that which only held a second rank, as to quantity, is now the chief component earth; the permutation goes round, till the earth, which existed in the most sparing quantity, now predominates to excess.

In such an infinity of variation, it is difficult to arrange the combinations of which these substances are capable. To derive the name of a class, or genus, from the predominancy of an earth, seems most eligible; and to consider

those as varieties of the same class, which are altered by the proportion of the second and third mixtures. Again, each of these varieties are susceptible of a multiplicity of modifications before an earth is so far diminished as to give an ascendency to another, or before the third rank of proportion has assumed that of the second or first. The simple combination of the earths, and their degrees of predominancy, may be thus arranged:—

	1st Variety,	2d Variety.
Argillaceous iron-stone	Iron	Iron
	Clay	Clay
	Lime	Silex
	Silex	Lime
Calcareous iron-stone	Iron	Iron
	Lime	Lime
	Clay	Silex
	Silex	Clay
Siliceous iron-stone	Iron	Iron
	Silex	Silex
	Lime	Clay
	Clay	Lime

As these become varied, they form the class of equalised mixture.

To assay any of these varieties, a flux peculiar to the nature of the mixture is necessary; so that the changes of proportion in the solvent ought to extend to seven, including the class of equalised mixtures, in order that the precise same quality of crude iron may be produced from all the varieties of iron-stone. The modification of each variety will be found to be sufficiently accurate, if assayed by the flux peculiar to itself. The arrangement of the three classes of ores into two varieties, each forming a distinct stage of combination, indicated by the predominancy of the first and second earth, are, with the neutral class, sufficiently minute for any purpose in the assay-furnace, and are sufficient to form an accurate and extensive knowledge of the analogy of these results with those in the blast-furnace.

Table of Proportions of Fluxes.

Let the earthy part of an argillaceous ore be composed of clay 9, lime 6, sand 3 = 18.

To assay	4	troy ounces of this ore	--	or	1920 grains,
add	4	—— bottle glass	—		1920
	3	—— chalk	—		1440
	0½	—— charcoal	—		240
	11½				5520

Let the second variety of argillaceous ores contain, clay 10, silex 7, lime 3 = 20.

In this case,	4	ounces troy of ore	--	or	1920 grains,
would require	4	—— bottle glass	—		1920
	4	—— chalk	—		1920
	0¾	—— charcoal	—		360
	12¾				6120

Let the first variety of the calcareous genus of iron-stone be supposed to contain, of earthy mixtures, lime 14, clay 6, silex 4 = 24.

When this iron-stone is to be assayed,

to	4	ounces troy	- -	or	1920 grains,
add	5	—— bottle glass	- —		2400
	1½	—— chalk	- - —		720
	0¾	—— charcoal	- —		360
	11¼				5400

Again, let the second variety of the calcareous genus be supposed to contain, lime 10, sand 6, clay 4 = 20.

I would add to	4	troy ounces	-	or	1920 grains,
	4	—— bottle glass	—		1920
	2	—— chalk	—		960
	0½	—— charcoal	—		240
	10½				5040

Let the first variety of siliceous ores be supposed to contain, silex 12, clay 8, lime 5 = 25.

For an assay of	4	troy ounces of ore	-	or	1920 grains,
add	4	—— chalk	—		1920
	3	—— bottle glass	—		1440
	0¾	—— charcoal	—		360
	11¾				5640

And, lastly, let the second variety of this genus of iron-stone be supposed to contain, silex 10, lime 7, clay 5 = 22.

To	4 troy ounces of the ore	-	or	1920 grains.
add	$3\frac{1}{2}$ ———	chalk	—	1680
	3 ———	bottle glass	—	1440
	$0\frac{3}{4}$ ———	charcoal	—	360
	$11\frac{1}{4}$			5400

Class of equalised mixtures, composed of, clay 7, lime 7, silex, 7 = 21.

To assay of this ore	4 troy ounces		or	1920 grains,
add	$3\frac{1}{2}$ ———	bottle glass	—	1680
	$2\frac{1}{2}$ ———	chalk	—	1200
	$0\frac{1}{2}$ ———	charcoal	—	240
	$10\frac{1}{2}$			5040

"Such are the proportions requisite to obtain, from all the various iron-stones, an accurate assay; the perfection of which is always indicated by the superior transparency of the flux, and the super-carbonation* of the metallic button. By scrupulously following these and similar proportions as the exigencies of the ore may point out, crude iron will always be obtained of the finest quality, carbonated beyond whatever is produced in the large way of manufacture, and its surface covered with a beautiful carburet of iron,† either in small shining specula, or in the state of a thin membrane. By a slight gradation of change in

* That is, containing a portion of carbon or pure charcoal *more* than sufficient to produce perfect malleable iron, but producing uniform fusible cast iron.

† By a carburet of iron, is meant, iron combined with a large proportion of pure charcoal, or carbon.

Malleable iron, is iron uncombined either with air or with carbon.

Blistered steel is iron with a small proportion of carbon.

Fusible, hard, cast steel, contains still more carbon.

Fusible smooth faced cast iron, still more than cast steel.

T. C.

the proportions of the component parts of the flux, the metal of the same iron-stone may be made to pass through all the inferior states.

Since, then, all iron-stones in the assay-furnace may be made to give out their iron at pleasure, of all the various qualities, it is surely erroneous to assert, that such and such iron-stones contain such and such qualities of iron; that this one affords metal of the finest quality, while that, on the contrary, yields iron fit only for forge-pigs or ballast; yet this is the universal language in the manufactory. In this, as in many instances, we accommodate the language to our ideas, rather than our ideas to truth. The suffrage of prevailing custom has imperceptibly associated with our ideas many absurdities which we are afterwards ashamed to acknowledge, and which darken the gleam of truth, or render it apparently ridiculous, merely because it is at varience with our prejudices. Where science guides not the manufacturer, or is scorned by him, his train of reasoning, though far from being just, is short; it is fitted to the narrow culture of his mind, and consonant to a barbarous nomenclature of received usage *.

* I cannot resist noticing one instance, prevalent at iron-works, of that blind reverence to the opinion of our predecessors, whose sources of knowledge must necessarily have been few and contracted. When super-carbonated crude iron is run from the furnace, it is frequently covered with a scurf, which when cold is found to be a coating of plumbago (carburet of iron) remarkably brilliant; sometimes in small specks, and at other times in large flakes: this substance is universally denominated *sulphur*, and, as the most expressive adjective for that quality, we say that the iron is *sulphury*. There are not, perhaps, two substances so opposite in their degrees of inflammability, or so widely different in their properties, as sulphur and plumbago; the existence of the latter almost wholly supposes a total absence of the former: yet, such is the want of investigation, or the slightest momentary reflection, that an indolent belief is passed as to the presence of a substance diametrically opposite to that which is expressed. *Sulphur* has hitherto been

In order to elucidate still farther how much the quality of the iron is dependent upon the proportions of the mixtures, in combination with or given to the ores, let a determinate quantity, say an ounce, of the oxyde of pure malleable iron be taken;—this we are physically certain contains no mixture except oxygen existing in quantity proportioned to the stage of oxydation, the quantity being ascertained by its degree of obedience to the magnet; when the quantity of oxygen given to it, by the decomposition of water, exceeds 25 *per cent.* few traces of magnetic attraction are perceptible:—introduce this oxyde into a covered crucible, without any addition, and expose it to a violent degree of heat for 40 minutes, (longer in proportion to the quantity,) a button of highly oxygenated crude iron will be obtained: if the heat is continued longer than is necessary to effect this, a small mass of malleable iron will be found occupying the bottom of the crucible. The produce in either case will be short of the real quantity of metal contained in the oxyde. When oxygenated crude iron is obtained, the ore from which it is produced, to use the common phraseology, is said to contain *bad iron.* That this has no relation to truth, will be seen by taking another portion of the same oxyde: let it be mixed either with chalk or lime, and a little bottle-glass, to constitute fusibility, and expose to a similar degree of heat with the former; the whole contents in iron will then be found re-

the philosopher's stone of the iron manufactory; to its presence is attributed the production of bad iron—when the metal is in its most valuable state, it is also *sulphury*;—it prevents cast iron from becoming malleable, and if *sulphur* were altogether absent, hard or white cast iron could not be produced. If cast iron is found coloured, it is by the *sulphur*; is it crystallised and coloured, then it has sulphur to excess; should it have lost its strength, or have become loose in the fracture by an excess of shrinkage in large castings, still it is by the agency of sulphur: in short, in every process in the manufacturing of iron, sulphur explains the whole phenomena! it is execrated in one process, and anxiously looked for in another.

vived, and occupying the bottom of the crucible in the state of fine carbonated crude iron. Here then is a complete alteration in the quality of the metal, though obtained from the same ore; for we cannot consider iron combined with oxygen, to which earthy bases are given, in any other light than that of an ore. Again, let a portion of mixture, exactly similar to the last, have added to it double or tripple its weight of bottle glass, and subject the whole to an equal heat with the former experiments, nearly a complete revival of all the metal will be found to have taken place; its quality, however, will be highly oxygenated and brittle. Such experiments clearly demonstrate, that the various qualities of crude iron are entirely owing to the mixtures in the ore, and their treatment; and that iron, considered as a simple metallic substance, is the same in point of quality in all ores.

If iron was originally formed in a metallic state, its property of decomposing water, whether casually exposed to a moist atmosphere, or removed at various depths from the surface, furnishes an hypothesis as to the primitive principle of iron ores; that part of the water—by far the greatest—which remained undecomposed, would serve as a medium, or vehicle of suspension, and conveyance to the oxyde; this again, in its turn, would be deposited either at the fountain-head, or at a greater or lesser distance from it, according to the affinities exerted upon it by other substances with which it might come in contact. Corresponding with this supposition, we commonly find those ores which are formed in vertical masses or knobs, approached by a great number of small veins occupying the smallest fissure or crevice in the rock. Time, and the re-action of additional water and acids, would a second time carry off a portion of the ore in chemical union; this, by the exertion of new affinities, would become precipitated, and mixed with the suspended earths, to form

regular strata of iron-stone. To such a primary and secondary agency of formation may be attributed the general superior richness of ores found in irregular vertical masses, to that of iron-stones. The same cause will also explain why more determinate qualities of iron are obtained from primitive ores, than from those of a secondary formation. In the former, the mixtures are commonly fewer, and the quality of the malleable iron more decided; in the latter, the quality of the metal is less certain, and more various, from the mixtures being more numerous. Hence we may also trace the reason of the superior qualities and marks possessed by some of the foreign fabrics over each other, where the same fuel has been used, and the same course of manufacture followed.

Having so far considered crude iron, in regard to its fusibility, and the facility with which it becomes changed into various degrees of carbonation or oxygenation, constituting a variety of qualities most pointedly distinguished in commerce, and in which the metallurgist discovers widely different properties and charateristic forms; I shall next proceed to mention in what manner strength may be given to any quality of crude iron which may probably be obtained by the fusion of an ore, and from what source this property is derived.

Upon a former occasion I have mentioned that iron, obtained from argillaceous ores, possessed a degree of strength beyond that obtained from the other genera. This truth daily presents itself to our observation in the large scale of manufacture; and however erroneous the reasoning of the manufacturer as to the cause, yet so evident are the consequences produced, that we must immediately attribute them to some source beyond the casualities of operation in the smelting furnace. In the explanation of this fact, as on the degrees of oxygenation and carbonation in general the manufacturer has recourse to the existent nature

of the iron in the ore, and denominates the metal contained in such and such an ore to be "strong, coarse, ill-melting iron;" or "weak, tender iron, possessing no body." That iron-stones and ores yield, in the operation of smelting, different qualities of crude iron, as to strength, is an undeniable fact; and that the same variety attaches to iron when converted to malleability is a truth daily evinced in our forges: yet these facts by no means entitle us to conclude, without farther investigation, that these varieties of strength are the hereditary property of the pristine formation of the metal. This inference accords with a hasty view of the matter, and a bare comprehension of effects, without tracing to its source the modifying principle of the whole. The theory which I have adopted, and which in every step I have found supported by numerous experiments, upon different scales, and by a long course of practical observation, explains to me, with much more ease and harmony, the whole phenomena of quality in ores and iron-stones.

To illustrate that part of my theory relative to strength, let the preceding experiment, wherein carbonated crude iron was produced from the oxyde of pure iron, be repeated with the addition of a little pure clay. If the clay added be half the weight of the lime also used, the iron will be found, when subjected to the gauge, much superior in strength; and if the experiment be accurately performed, the metal will be but a little reduced in point of carbonation. The following proportions will give accuracy to the result:—Oxyde of iron, 4 parts—Lime, 2—Clay, 1—Glass, 3 = 10 parts. By mixing clay with the flux in all experiments, the strength of the crude iron is improved. This point may be urged so far as to form, by an extra-addition of clay, a flux of difficult fusion; in which the iron becomes suspended in globules, which are partially malleabilised apart from each other. Crude iron,

obtained with a superior mixture of clay, in all its stages of quality, possesses a greater degree of strength than iron from calcareous iron-stones. Iron from argillaceous iron-stone is reckoned strongest when carbo-oxygenated; that extracted from calcareous iron-stone is reckoned to possess most strength when oxygenated, mottled.* I would far exceed the limits of the present communication, were I to enter fully into this curious subject, and particularise the different results obtained by the fusion of ores with different earths in various proportions: all my experiments have fully proved to me, that originally the quality of the iron, simply considered, was the same; that, as it underwent change by decomposition and new combination, it became united to foreign substances, possessing widely different properties; and which mixture, by a general fusion, imparts to the metal various properties, seldom homogeneous, but frequently otherwise: in short, that the numberless mixtures with which it is combined are not neutral in fusion, but convey an alteration to the quality of the reduced iron. I hope to resume this subject when my experiments will be more extended by the examination of a vast variety of iron-stones, and shall then point out the consequent effects of their application to the manufacture of cast and malleable iron.

The assaying of primary ores† comes next under consideration. These, I have already said, possess a much greater diversity of external character, as well as internal variety, than those of iron-stone. When assayed with a vitreous flux, either of salts, alkalies, or silex, the results are rendered very uncertain and erroneous: when pot-ash, tartar, &c. are used, the crucible is often destroyed, and the compound entirely lost: when bottle glass and a mixture of these are used, the scoria formed is so very black

* I cannot comprehend this. T. C.

† Ores found in primitive formations. T. C.

and ponderous as to give the most presumable indication of the secretion of metallic oxyde: this is afterwards verified by fusing the mass with a mixture of dried chalk and charcoal, a globule of metal will be obtained, which evinces the richness of the scoria; this, having lost its colouring principle (the metal), becomes clear and transparent. The results from these ores by fusion afford various products, and lead to different conclusions: I shall mention several of them.

The Cumberland iron ore, when introduced into a crucible without any additional mixture, fuses easily, and forms an opaque scoria, internally of a black colour, but towards the surface covered with fine shades of brown: this arises from a partial oxygenation of the semi-revived metal while cooling, and is often injured by a fresh combination of oxygen.* If the crucible remains sound, and the melted mass is kept in a state of extreme division for an hour, a considerable quantity of metal will be found precipitated, but so highly oxygenated as to shiver to pieces if exposed to air before it is entirely cooled. If, when the crucible is taken from the furnace, it be slightly inclined to one side, and the vitrified fluid entirely removed from the surface of the metal, a violent deflagration will immediately ensue, the ejected globules will be thrown three feet upwards from the mouth of the crucible: if the quantity of metal does not exceed 500 grains, it will totally disappear, except a rough dark-blue oxyde in the bottom of the crucible, not above 1-4th of the original weight. The metal thus oxydated* will be found in small spherules of a blackish colour, and spongy around the spot occupied by the crucible.

This curious appearance is in fact a combustion of iron by oxygen gas, furnished by the decomposition of atmospheric air: it is an operation which the accurate observer

* By being exposed to the atmosphere. T. C.

may daily see manifested in almost every department of the foundery and forge. By a just comprehension of it, and a proper appreciation of its effects, we have a key for the elucidation of the source and action of many facts long wrapped in mystery, or which have been explained upon principles destitute of stability, and unallied to the fundamental operations of truth.

In place of withdrawing the crucible immediately upon the separation of the crude iron, were it to remain for an hour longer under an inferior degree of heat, so as to consolidate the metal without again fusing it, then the whole mass would be found malleable; the scoria light and porous. In one of my experiments upon the hæmatites variety, I obtained from 1 lb. avoirdupois, or 7000 Troy grains, an ingot of fine malleable iron weighing 4486 grains; a produce equal to 64 *per cent.**

An oxygenating flux was however used, and nearly the whole contents in iron previously revived. In experiments without the addition of a flux, the transmutation from cast to malleable iron is shortened, but the produce is not more than 5-8ths of the intrinsic contents of the ore. Even this process may be considerably shortened by removing the covering of vitrified earths floating upon the surface of the metal: thus the small portion of the carbonaceous principle constituting fusibility is almost instantly carried off by the combination of oxygen; the metal loses its fluidity, becomes thick and clotted, and more speedily passes into the malleable state. In this process the quanti-

* This might be adduced as a proof that crude iron contains more parts congenial to malleability than is generally admitted, or than is manifested in the operation of converting it into malleable iron at the forge: the loss there has already been mentioned to amount to from 30 to 50 *per cent.* of real metal; in this assay, however, the produce in malleable iron was only 4,5 less than when accurately assayed, and rich carbonated crude iron was obtained; in which, too, the carbon constituted a part of the weight.

ty of malleable iron obtained is still less than in the two former: the surface of the metal being exposed by the removal of the scoria, oxydation takes immediate effect; and whilst malleability is pervading the under surface of the metallic button, the upper one becomes reduced to a blackish blue oxyde. Here a striking proof is afforded of the great affinity which oxygen has, in high temperatures, to heat or caloric. Were the surface of such highly oxygenated crude iron exposed, while fluid, to atmospheric air, at an ordinary medium, for 1-6th of the time, its whole metallic properties would be completely destroyed: in the present instance nearly one-half of the metal is preserved, although its surface is exposed to the action of a violent current of gas, (air) ignited to the highest pitch of whiteness*. In the proper assay of this ore I have

* I have frequently observed, in experiments with pretty deep crucibles, where the most violent heats were excited, and where the fluid metal had assumed a whitish-blue colour somewhat inclining to azure, that the quantity of oxyde formed was imperceptible, and never visible while the heat was continued of equal intensity; when this agent became less urgent, the surface of the metal became oxydated as usual. When a regulus of crude iron thus exposed was wished to be obtained free from oxydation, a little dry charcoal was introduced into the crucible so as to cover the regulus; this prevented the action of the air from taking effect while cooling, and preserved the button smooth. During such exposures, when no oxyde was produced, I have noted a loss of metallic parts equal to 5.7, or 10 *per cent.* when the space of time did not exceed one hour. Among several conjectures respecting the cause of this deficiency in weight, and real abstraction of metal, the two following have with me most weight. 1st, Either the metal deflagrates in small particles, which are thrown out of the crucible in sparkles, made invisible by the transcendent brightness of the surrounding heat: Or, 2d, that in consequence of the fluid metal being exposed to such a degree of heat, in contact with oxygenous gas, part of it becomes acidified, and forms the ferric acid,*

* This acid has never yet been shewn. T. C.

found all the varieties susceptible of various degrees of carbonation: for the most part I have used chalk and charcoal for the reduction of the ore into carbonated crude iron. In the hæmatites variety, for 1 lb. avoirdupois I have commonly added 6 oz. dried chalk* and 3-4ths oz. of charcoal; and for the splinty blue ore also a similar mixture. From both of these I have obtained the richest sort of crude iron. In the manufactory, these varieties are always reckoned to produce the hardest and most infusible qualities of crude iron: when the metal is subsequently manufactured into bars, it is stated at different places to produce cold and hot short iron.

The kidney ore will admit of a diminution of chalk, and a small addition of glass; 1 lb. avoirdupois of this variety will be accurately assayed with the addition of 5 oz. chalk, 1 oz. of glass, and 3-4ths oz. charcoal. The same proportion of mixtures will also accurately reduce the small pieces of this ore, commonly of a soft, greasy consistency, mixed with small fragments of the hæmatites and kidney, and will give out the iron which they contain super-carbonated. A mixture of this soft ore with kidney is preferred to the richer varieties at the iron manufactories. The Lancashire ore chiefly consists of this compound, and the poorer in iron has always a decided preference given it at the blast furnace.

The stratified iron ore of the island of Islay is of most difficult fusion when treated without any addition. It fuses into a blackish green ponderous mass, and, even exposed to the highest heats, lets fall but a small share of its iron. The quality thus obtained is in the highest degree oxygenated; its fracture is partially crystallised in lines which converge towards the upper surface of the button, similar in crystallisation to the fracture of zinc. A regulus thus obtained, when divested of its scoria, and pro-

* Instead of chalk, pure limestone or marble might be used. T. C

perly exposed to the action of the ignited gas, soon loses its fluidity, and passes into the state of strong malleable iron. If this operation is performed upon a large quantity, without agitating or turning the mass, the upper surface of malleable iron will early acquire the cold short quality, and will be subject, at the same time, to an uncommon waste by the rapid oxydation of its parts. In assaying this ore for the production of carbonated crude iron, the results are obtained with considerable difficulty; seldom perfect till the second or third experiment. This is chiefly owing to the great variety of quality in the stratum, two pieces seldom being alike either in appearance or in reality. The inferior masses yield from 44 to 48 *per cent;* and the superior qualities I have found as rich as 56 to 61 *per cent.* To obtain carbonated crude iron from the richest varieties of this ore, add to 1 avoirdupois lb. of it, 7 ounces of dried chalk, 3 of bottle-glass, and 1 of charcoal. This mixture will produce soft crude iron, possessing great strength, and an uncommonly large crystallised grain. The poorer qualities require an additional quantity of calcareous earth, to restore the equilibrium lost by the substitution of silex in place of iron. This ore had a trial in the large way at Clyde Iron Works, but was found to yield *bad* iron with the *usual* proportion of fuel.

Opposite in its quality and results is the Swedish ore of the island of Elba. This, when presented to a requisite proportion of carbonaceous matter, to take up its oxygen, not only clears itself of this hurtful mixture, but also takes up a considerable portion of carbon, which, in fusion, becomes united to the metal, and constitutes it perfectly carbonated. In experiments with this ore, I found that when 2 oz. of it were treated with 2 and a half oz. chalk, half an oz. bottle-glass and a quarter oz. charcoal, the mixture was with difficulty reduced to a white glass; which at no time had been sufficiently divided to allow a general gravitation

to the many globules of beautiful carbonated iron thus separated. In fusion, therefore, *per se*, the metal precipitated becomes greyish, and, in many instances, affords similar results to a pure calcareous iron-stone ; with this principal difference, that it abounds with nearly a double quantity of metal, whose tendency to become carbonated is noways inferior to any iron-stone of that class. A smooth carbonated regulus will be obtained from this ore, by using the following proportions : Ore in a raw state, 2 ounces ; chalk, 2 ounces ; bottle-glass, 1 1-2 ounce ; and charcoal, quarter oz. The scoria resulting from this fusion will be of a light-blue colour, clouded, and variegated like an agate, and very transparent. The great distance of Elba from this country precludes the possibility of using this ore in our manufactories with any profit, unless it could be brought home as ballast, and delivered in the vicinity of any iron-work at 22s. per ton. The products obtained from it in the assay-furnace, indicate, in an uncommon degree, how very valuable the quality of crude iron would be in the scale of manufacture, by its application.

The Norwegian, Danish, and Swedish ores, found in strata, resemble, in many points, the Scotch ore of the island of Islay ; in assaying them a similar treatment is necessary. Some of them are more fusible, and afford singular qualities of crude iron. When fused with oxygenating fluxes, the metal produced is uncommonly hard and brittle ; exhibiting a fracture studded with brilliant mirrors, diverging the light in small radii : even when fluxes are used, capable of conveying carbonation, the metal exhibits this bright granulated fracture in a great degree. One of the ores from the mine of Houban, upon being exposed a considerable time after separation, afforded a mass of pretty good steel. The proportions necessary to assay these, with accuracy, so intimately depend upon their richness, and the relative proportions of mix-

ture with which the iron is combined, that the same recipe can seldom be applied to more than one variety. As iron-stones are more defined, and their treatment prescribed by more certain rule, a knowledge of them will soon lead to a just comprehension of the primary ores; a second experiment, therefore, with any of them, will be sufficient to point out the necessary proportions for obtaining in the next assay carbonated crude iron. In one collection of Norwegian ores I found the following variety:—

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	
parts	18	21	35	47	55	63	iron
	17	16	19	11	24	19	volatile
	65	63	46	42	21	18	earths
	100	100	100	100	100	100	

This simple table will shew plainly how necessary it is to accommodate the flux to the variety of the ore. If from this collection you wish to obtain carbonated regulus, it is obvious that, in order to saturate them equally, the iron contained in No. 3 ought to be presented with double the quantity of carbon necessary to carbonate No. 1; No. 5 with a triple quantity; that of No. 6 with more than 3 and a half: and as I have proved that this effect will be chiefly produced with the use of a calcareous earth, it will at once be conceived how far this substance is to be used as the instrument of alteration.

In the recipes adduced in this and the preceding paper, I have always noted charcoal as a constituent of each mixture. Since I discovered that the *contact of calcareous earths conveyed carbonation to the metal, by the decomposition of the carbonic acid*, I have reduced the proportion of charcoal commonly used in the flux, and have, in the treatment of most iron-stones, even abandoned it altogether: however, as my experiments have not yet extended universally to primary ores, I have, in the mean time, retained it as a constituent part of the solvent.

The ore being thus analysed, it may be submitted to the common processes in the large way.

Roasting. If the ore on being pounded and exposed to a full red heat, gives out any sulphureous vapour, it should be roasted, by placing it in wedge-like heaps, and leaving openings for a fire. The ore thus roasted with a full red heat for 10 or 12 hours, will part with nearly all its sulphureous and watery parts. But unless it be stratified with charcoal dust, the current of air will oxygenate it, and render it still less metalline than before, and cause it to require a greater charge of charcoal, and a longer time in the smelting furnace. Mr. Mushet proposes roasting the ore in a separate furnace, but this would appear here, a plan too complicated.

The common method as detailed by Dr. Aikin, is as follows. 1 Chem. dict. 596.

The first process that the iron-stone undergoes after it has been broken into pieces not larger than an egg, is roasting. This is sometimes performed in cup-shaped kilns, the bottom being occupied by lighted coals and the kiln then filled up with ore, which by the time that the fuel is consumed is found to be sufficiently torrified. The most usual way however of burning iron-stones is the following. Upon an oblong piece of firm and level ground is laid a bed of small coal from four to eight inches in thickness; upon this is placed a stratum of iron-stone composed of pieces as nearly as possible of the same size, and from 18 inches to two feet thick: the upper surface of this is then rendered more compact by filling up the interstices with smaller pieces of ore. Upon this rests a layer of small coal not more than two inches thick, and on this as a base, is reared a gradually diminishing pile of ore so as to resemble the ridge of a house; finally, the whole external surface receives a compleat covering of small coals and coal dust. The pile is kindled by applying burning

coals to the lower stratum, which by degrees ignite the whole mass. The breadth of the pile at the bottom varies from 10 to 16 feet, the usual height is about five feet, and the length varies from 30 feet to 60 yards. When the coals are consumed the pile gradually cools, and in eight or ten days may be wheeled away to the furnace.

The ore if well roasted will now be of a reddish brown colour, of diminished specific gravity, and will have become magnetical: the sulphur, water, inflammable matter, and carbonic acid that it originally contained, will have been dissipated, and it is now ready to be smelted.

The following remarks and experiments by Mr. Mushet, throw great light on the theory of roasting, or torrefaction. 3 Phil. Mag. 200.

The burning or torrefying of iron-stones, known in the large way by the rather improper term of *calcination*, consists in exposing the stone to a certain degree of heat in contact with air, in order to dispel those substances which it contains, capable of assuming the aëriform state by the combination of caloric. This operation ought to be performed in a progressive heat, always short of fusion. The water is then slowly evaporated without being decomposed; the caloric unites to the carbonic acid, which soon assumes the gaseous state; and lastly, the sulphur, if any, sublimes.

This process is essentially necessary to be performed before the iron-stone is introduced into the blast-furnace. Were raw iron-stone, or ore, precipitated in the violent heat of the smelting-furnace, the water and acid would instantly be decomposed; the oxygen would partly unite to the iron in addition to the fixed quantity peculiar to each ore, and part of it would oxygenate the sulphur, either of the ore, or of the pit-coal, a portion of which is always present in the furnace. The whole mass would then be precipitated in fusion, and a dark porous lava obtained,

containing iron more difficult to be revived than ever, owing to the great quantity of oxygen combined with it. In cases of this kind, the disengaged hydrogen manifests its escape, by changing the colour of the flame from a mellow white to a pale sickly blue.

It must from all this appear obvious, that, when torrefaction has been properly conducted, a very considerable part by weight of the whole will be dissipated: the absence of these volatile substances always leaves the iron-stones more or less magnetic. The loss of weight, however, is very different in the various classes of iron-stones, even when they are all exposed for the same length of time to a degree of heat capable of expelling those mixtures, which, under such circumstances, assume the gaseous state.

1. Calcareous iron-stone, when properly exposed to torrefaction, loses more of its weight than either of the other two classes. Where the lime is abundant, I have found this iron-stone lose 38 per cent. but more commonly 35 and 36 per cent. of water, carbonic acid, and sulphur.

2. Argillaceous iron-stones, exposed to a similar degree of heat, and treated in the same manner, commonly lose in weight from 32 to 35 per cent.

3. Siliceous iron-stones always give out less weight when exposed to torrefaction under similar circumstances with other stones. In common they lose from 27 to 30 per cent. I have, though rarely, found them to give out 25 per cent. only.

The extreme loss of weight in each class must be considered as the utmost point to which torrefaction can with safety be urged, without exposing the iron-stone to an accumulation of weight by the combination of oxygen.

From the variously compounded natures of iron-stones arise the various calculations of the loss which they are said

to sustain in burning at different iron-works. Fields of iron-stone are commonly impressed with a general distinguishing characteristic feature: some are of the calcareous genus; some of the argillaceous; and others again have a more intimate alliance with silex than the former two. Hence we find, at those works where the chief supply is drawn from the argillaceous iron-stones, that the loss in torrefaction on the great scale is computed from 30 to 33 per cent. Where calcareous iron-stones form the chief supply, the loss is estimated at from 35 to 37 1-2 per cent. Few or no iron-works are obliged to have recourse to iron-stones abounding with sand for their chief consumption: a general estimation of the loss sustained by this stone in the large way is therefore difficult to be made, though, I have heard, that at some works 25 per cent. was all that was allowed to be expelled during burning. Nature has been extremely kind in the formation of our secondary ores of iron; as the bulk of them, that contain iron sufficient to entitle them to be smelted, are combined with superior proportions of clay and lime.

As the burning or torrefying of iron-stones is of great importance to the manufacturer, and as it may be in some respects gratifying to the man of science, I shall particularly enter into the various phenomena attending the operation; dividing torrefaction into two classes: that which deprives iron-stones of certain substances capable of becoming aëriform by the combination of caloric in contact with atmospheric air; and that which deprives ores of their oxygen—hence called de-oxygenation—by heating them in contact with charcoal, in closed vessels, or in cavities impervious to the external air.

1. The consequences of heating iron-stone exposed to air is a loss of water, sulphur, and carbonic acid*. A

* I have seen some iron-stones in torrefying deposit a beautiful oxyd upon their surface, of a lake colour, and light as down. The

small proportion of oxygen may at times be unfixed, when the fuel may chance to come into contact with the heated iron-stone under a partial exclusion from air. But the association of circumstances necessary to effect this can so seldom be the effect of chance, that it is never to be looked for with certainty. When the operation is properly performed, the last particle of acid and water may be expelled. But this point is difficult to be ascertained with any degree of exactitude: for, in proportion as these gaseous substances are carried off, the metal becomes more and more revived, of course more and more liable to attract, and fix oxygen by the decomposition of the ignited gas; and, as the last portions of the acid and water are distilling, the stone is apt to gain weight by the calcination (oxygenation) of its iron. This will positively be the case when the heat is carried beyond the necessary degree, and is indicated by the iron-stone swelling in bulk, becoming specifically lighter and porous on the surface, but gaining weight in a great degree internally. As oxygenation goes on, the magnetic virtue decreases, until at last it becomes entirely annihilated.

The first stage in torrefaction is indicated by the first general change of colour in the iron-stone. This is com-

same substance, I have observed, effloresced upon the surface of the fracture of highly oxygenated crude iron, which had been broken immediately after the metal had lost its fluidity. From this coincidence of effect, I am inclined to suppose, that the oxyd deposited on the iron-stone in burning, is the consequence of the decomposition of the sulphuric acid; a portion of which had been mineralised with the stone, holding iron in solution: and that in the latter it was occasioned by a superabundance of oxygen in the blast-furnace, probably from the introduction of raw iron-stone, which had escaped the effects of the fire: that the sulphur, as formerly stated, had become oxygenated, dissolving a portion of the metal; which was again deposited in the state of a calcined sulphat, when the acid was suffered to escape, by being freely exposed at a high degree of heat to open air.

monly a faded blood colour, more or less dark according to the quantity of lime present.

I have repeatedly made use of all the various iron-stones, in the state of a fine powder, in order to ascertain what was the weight lost by each class in its transition from its native hue to the first stage of an assumed colour. And I am enabled to state the following as an average of the results obtained on this head: Calcareous iron-stones give out six parts in one hundred of the raw mineral: argillaceous iron-stones, five; and siliceous iron-stones, four and a half.

If the pulverised iron-stone is thrown into a vessel red hot, this loss will be effected in two minutes. The change of colour is immediately effected on those parts in contact with the heated iron. The whole is brought into contact with it; and when thrown out, the magnet will be found to have acquired a perceptible influence over it. When the powder is first thrown in, a slight decripitating noise is heard for a few seconds. This operation may also serve to shew the presence of sulphur, or of its acid. When in the former state it instantly takes fire, and burns with a dark lambent flame. When the acid is present, it is easily known by the suffocating fumes disengaged by the action of heat.

The application of heat beyond the first stage of colour, causes the iron-stone to pass through a variety of shades. These, as in metallic substances, are the effects of the presence of air at certain degrees of heat*. As the progressive dissipation of the volatile mixtures takes effect, the colour deepens; and, according to the nature of the iron-

* From smooth-surfaced iron-stones and ores, when exposed to heat partially sheltered by charcoal dust from the action of air, I have obtained all the shades of colour peculiar to polished iron and steel; but with less of the metallic lustre, owing to the surface being more porous.

stone, becomes fixed, of a brown, dark brown, or deep claret colour. These indicate the almost entire expulsion of the water, acid, &c. In this state, all iron-stones are possessed of magnetic attraction, and exhibit the various phenomena already described, as being peculiar to their respective natures.

The methods commonly in use for torrefying iron-stone, in the large way, are of two different kinds: that of burning in kilns or conical furnaces; and that of exposing iron-stone in open air, stratified with coals, to combustion. The former is used in some places in Wales; the latter is almost universally adopted in England, and totally so in Scotland.

In the operation with furnaces, they become filled entirely with iron-stone, except a stratum of coals in the bottom, which is afterwards inflamed. The combustion is then carried on by means of a current of air passing through the furnace, and forcing the heat along with it. When the iron-stone is deemed sufficiently burnt, the register is shut up; and the combustion, no longer maintained by means of external air, soon dies away, and leaves the furnace to cool.

The most common method, however, of burning iron-stones consists in levelling a piece of ground, and covering it with a layer of small pit-coals. This is of various thicknesses, 4, 6, or 8 inches, according to the height the pile is to be built, and the nature of the iron-stone. Upon this stratum of coals the pieces of iron-stone are imbedded, as near to the same size as possible, in order that all may be equally acted upon. These are reared to various heights, 18, 20 to 24 inches, the determination of its height depending upon circumstances. The surface is a second time levelled, by introducing small pieces of iron-stone betwixt the interestices occasioned by the angles of the larger. This again receives a covering of small coals,

seldom exceeding 2 inches in thickness. Upon this is reared the subsequent building, always gradually narrowing itself till it has assumed the shape of a stout wedge, with its base resting upon the ground. After this is effected, the whole of the external surface receives a complete covering of the smallest sort of coals. The pile is kindled by applying burning coals to the ground stratum. This creeps slowly along; heats the stone upwards; kindles the second layer of small coals, and ultimately inflames the whole mass from top to bottom.

When the coals are consumed, the pile gradually cools, and in 8 or 10 days may be wheeled away to the furnace.

The quantity of iron-stone burnt at one time is various at different and even at the same places; some kinds require to be burnt in smaller heaps, owing to their nature and fusibility. At some works the fires extend from 50 to 60 yards; and it is not uncommon to see skilful workmen, at one end, adding fresh materials to the burning pile; while others, at the opposite end, are employed wheeling away that which the fire has left sufficiently burned for the purpose of the furnace. Fires that extend from 30 to 60 feet in length are more common; from 10 to 16 feet wide, and about 5 feet high.

At most iron-works a local opinion exists, to what degree of heat iron-stone ought to be exposed before it is properly fit for the blast-furnace. All, however, agree that burning is necessary; though few give an accurate reason why. The only one I have heard adduced is, that iron-stone is *calcined* in order to burn out the sulphur and other *heterogeneous* mixtures. Hence arise a diversity of opinions, chiefly founded upon individual notions of the fixity or volatility of sulphur. Some contend that sulphur is easily displaced, and that therefore the iron-stone should be moderately *calcined;* lest the sulphur from the coal used in burning it should enter, and again hurt the

quality of the iron. On the other hand, it is said that sulphur is of difficult expulsion from the centre of the stone, as it is never seen going off till a bright red heat forcibly expels it; and therefore it is highly requisite the iron-stone should be long and violently exposed till the last portion is got rid of. To effect this, therefore, the heat, say they, ought to be urged till such time as the stone has indicated signs of fusion, or has partially suffered thereby. In order to give strength to this opinion, those who adopt it add, that, by such severe *calcination*, the volume of stone is reduced, becomes heavier, and that it will consequently occupy less room in the blast-furnace; of course it is imagined that, bulk for bulk, the iron-stone becomes richer in iron than when in a raw state.

Those who are acquainted with the oxydation of metals, and the consequent increase of weight, will at once discover the source of this error, and readily conceive, that, after the metal in the iron-stone has become partially disengaged by the expulsion of water, carbon acid, sulphur, &c. forming frequently a third part of the whole weight, it will become an object of attack to the oxygen of the atmospheric air, the combination of which with the iron, alone adds to the actual increase of weight, and not the transposition of the particles of metal from one piece of iron-stone to another. It must also be obvious that, where such fallacious prejudices have taken root, the consequences must frequently be fatal to the interests of the manufacturer; as such iron-stones, literally calcined, must require an additional portion of fuel to furnish carbon to carry off the superadded oxygen.

It is somewhat remarkable that the phenomena attending the oxydation of iron should be entirely unknown at iron manufactories. Such a process is never dreamt of, and even the declaimers against severe torrefaction only account for the increase of weight, by asserting that the

earthy parts are burnt out and nearly consumed, and that the metallic parts only remain, destroyed however in their nature and *reduced to a cinder.*

We are not to wonder, therefore, at the uncertain results which the untutored manufacturer obtains, until such time as a long course of experience has taught him, that, by combining certain causes, good or bad effects are the consequence. Even at last he still rests upon an unstable basis; destitute of the correct operation of principle, and incapable of preventing an evil from a total ignorance of its real source of action, he can only in the end avoid it after a multiplicity of movements, wherein he finds his practical knowledge increased at the expence of a considerable sacrifice of property.

How much more enlightened would be the mind of the manufacturer, were he to attend minutely to the phenomena developed in all the stages of his process, and satisfy himself as to the radical principles of action in each individual stage! In doing this, chemical minuteness, the terror and butt of the unphilosophised mind, is not absolutely indispensible; and yet every thing may be ascertained necessary to be known for the production of certain determinate qualities of crude iron.

He would then easily comprehend that all iron-stones contain less or more water of crystallisation, and that, being combined with a certain proportion of lime neutralised with carbonic acid, it is necessary that they be exposed to a heat sufficient to expel the first and last of these as well as sulphur. The reason has already been given, and the consequence shall be once more stated. The evil effects produced by introducing raw iron-stones into the blast-furnace, are less owing to the small portion of sulphur contained in most of them, especially in balls, (the vapours of which arise even from the softest crude iron when fluid,) than to the decomposition of water and

acids, each of which gives up a proportion of oxygen to the metal chiefly before separation is effected.

Does it not then unquestionably follow, that if the quantity of charcoal in the furnace formerly was sufficient to take up the oxygen existing in the ore, and to afford carbonated crude-iron, that if a further quantity of this principle is added, by whatever means, part of the charcoal which formerly went to carbonate the iron now combines with the superadded oxygen to form carbonic acid; of course the metal will be deprived of its carbon, become white in the fracture, and may then justly be denominated oxygenated crude-iron. The same application to principle would also inform the merely practical man, that when iron-stone is completely deprived of those substances which assume the gaseous state by the combination of caloric at a moderate temperature, it is then sufficiently prepared for the furnace. This is always indicated by the colour which the stone assumes varying from a brown to a dark claret. Blues always succeed this shade; and the smallest appearance of blue, however light, is a certain sign that the external air has made an impression upon the particles of metal, by superoxygenating them. Instead therefore of expelling a further quantity of *heterogeneous* matter, a principle is added the most noxious and destructive to the existence of iron in a metallic form.

The phenomenon of iron-stone becoming heavier in the fire, would no longer be explained by assuming vague assertions incompatible with and inadmissible to common sense. Upon finding two pieces of iron-stone in the same fire, which have to appearance been affected in a widely different manner by the heat; the one heavy, of a black blueish colour; the other light and porous: the practical man would now no longer say that the metal from the porous piece had escaped by these pores, and entered into the ponderous one; and that the accumulation of

weight in the latter was entirely owing to it abstracting the metal from the former. Widely different indeed would be the conclusion. He now would have learned that metals are combustible bodies; that under certain circumstances iron is one of the most inflammable in the group; that, during its combustion, it decomposes the air that maintains the combustion, and fixes one of its elements in spite of the powerful affinity exerted upon it by the caloric; and that by this process alone it increases its volume and weight. The porous mass of iron-stone would now be described as having had its iron completely saturated with oxygen at a very high temperature; that an imperfect state of fusion had been the consequence; and that a combination of these circumstances, acting for a considerable length of time, had volatilised and carried off a very considerable portion of the metal.

On the same principle would be explained the increase of weight in the more ponderous piece; it would then readily be conceived, that the same association of circumstances had not been present; but that the iron had gained in weight by the addition of oxygen at a temperature short of fusing and volatilising the oxyd.

Having in the former part of this paper stated the average loss which the various natures of iron-stones sustain when exposed to torrefaction in external air, I shall now simply state the quantity of oxygen which the various classes are apt to imbibe when exposed to a high temperature, after those volatile mixtures capable of assuming the gaseous state by the combination of caloric have been expelled.

The facility with which iron-stones become oxydated is entirely dependent upon the nature of the mixture constituting fusibility or otherwise: so that were argillaceous, calcareous, and siliceous iron-stones, previously de-oxygenated, exposed to the same degree of heat—a degree

capable of oxydating their iron—the result would be, that the quantity of oxygen combined would be in a relative proportion to the fusibility of the mixtures, for a determinate space of time. The argillaceous iron-stone would be found in a given time to have gained least; the calcareous a larger portion; while the siliceous, containing an assemblage of mixture fusible at a degree of heat in which the former would remain unchanged, will be found to have gained the greatest weight; but if exposed to an high temperature for a sufficient length of time, the oxygen absorbed will be in an exact proportion to the iron contained in the stone; only, the siliceous iron-stones arrive soonest at a high pitch of combination. In the course of many experiments I have found the following proportions to be nearly just, when the quantity of iron contained in the respective stones was nearly analogous.

Argillaceous iron-stone, which has yielded me 38 per cent. in the assay-furnace, first distilled and afterwards carefully de-oxygenated, increased in weight, during an exposure to ignited gas for 8 hours in the bottom of a deep crucible, 22 per cent.

Calcareous iron-stone, which afforded a similar quantity of metal, and which was subjected to the same train of preparation, to dispel its volatile mixtures, and unfix its oxygen, gained in weight nearly 23 per cent.

Siliceous iron-stones, containing from 36 to 38 parts of iron in 100, treated in the same manner, afforded me instances of an accumulation of weight equal to 24 to 25 per cent.

In order more particularly to illustrate the double phenomenon of iron-stones first losing and then gaining weight, I shall insert the treatment of one particular stone of each class; from which a positive judgment may be formed of the general operation, and results, peculiar to each.

1. There were introduced into an iron test some pieces of *argillaceous* iron-stones, weighing - 1750 grs.

After being exposed to a bright red heat for 8 hours, and then allowed to cool, they weighed 1160

Lost in simple distillation - - - 590 grs.

Equal to 33·6 per cent. Specific gravity in this state 2,52150.

The stone had now assumed a claret colour, and was possessed of regular internal fibres, adhesive to the tongue, obedient to the magnet, and exhibiting every property peculiar to excellent iron-stone.

I returned the residue, which, as above, weighed 1160 grs. and exposed it in an open crucible for 4 hours to an increasing heat till a slight degree of fusion was perceived to take place. This was indicated by the angles of the pieces becoming rounded, and swelling a little in bulk—When cool they were found slightly porous, and weighed - 1309

Increased in weight by the combination of oxygen - - - - - - 149 grs.

Equal to 12.8 per cent. Specific gravity in this state 3·3636.

The fracture of the pieces now wore a semi-vitrified appearance, of a dark blue colour, inadhesive to the tongue, unmagnetic, but much more metallic and ponderous.

A *calcareous* iron-stone treatedafter the same manner, of which I also used small pieces, weighing 1750 grs. which had yielded a similar product in iron in the assay-furnace with the former, when cool weighed - - - - - 1090

Lost in simple distillation equal to 37·7 per cent. - - - - - 660 grs.

The fracture of this iron-stone was now of a bright brown colour, streaked with lime, faintly marked with internal fibre, less tenacious to the tongue than the former class, but equally obedient to the magnet.

The residue, weighing as above - - 1090 grs.
was returned to the furnace, and exposed in the bottom of a deep crucible, till such time as a slight indication of fusion was observed; when cooled, the pieces weighed - - - - 1235

Gained in weight by the fixation of oxygen equal to 13·3 per cent. - - - 145 grs.

In its present state this iron-stone, in point of colour, resembled the former.

Its fracture, however, was smoother, and more vitrified, equally destitute of tenacity to the tongue, and obedience to the magnet.

3. An iron-stone, which contained a proportion of *siliceous sand*, was exposed under similar circumstances to the same degree of heat—quantity used 1750 grs.

When properly torrefied, weighed - 1248

Lost in simple distillation equal to 28·6 per cent. - - - - 502 grs.

The appearance which this stone had assumed was of a reddish, small, granulated fracture, considerably magnetic, but scarcely possessing any degree of adhesion to the tongue.

The residue, weighing as above - 1248 grs.
was exposed to an equal degree of heat with the former classes, by which the stone suffered throughout a slight degree of fusion—when cool, the connected mass weighed - 1431

Gained in weight by the combination of oxygen equal to 14·6 - - - 183

The colour of the stone was now changed to a black, vitrescent, slightly porous mass, hard and refractory. I have not given the specific gravities of the two last natures of stones: iron-stones containing equal portions of iron, in similar states of preparation, vary little in their specific gravities.

It will no doubt be observed, that the increase of weight in these statements tally not with the sums formerly given: the amounts there adduced are results from iron-stones which had been previously deprived of most of their oxygen; but in these, the extra quantity of oxygen taken up by the stone is only given, forming an aggregate, with the original existing quantity, as shall hereafter be shown, nearly corresponding to the sums first given. From these experiments, singled out to convey a just idea of the changes to which iron stone may be subjected, it becomes obvious, that all the varieties of iron-stone are capable of decomposing atmospheric air at a certain temperature, and of fixing a portion of its oxygen, whereby weight is gained, by each, nearly equal to one-eighth of its original quantity.

It must also from this appear obvious, that the burning of iron-stone is an operation—though hitherto conducted by chance, exposed to all weathers—of the greatest nicety, and consequence, to the certain and economical manufacture of cast-iron; wherein a small addition of fuel, by exciting a high temperature, exposes the iron to the combination of a hurtful principle, in quantity (as will hereafter be shown) almost equal to what the metal was originally precipitated in. The extra proportion of fuel, therefore, requisite under circumstances where a severe mode of torrefaction is either universally adopted, or where it is frequently the result of inattention and want of skill, though as yet unascertained upon a large scale, must be very considerable.

I look upon it therefore to be a great desideratum in the preparation of iron-stone, to contrive a mode which would unite certainty and economy; a mode which would either de-oxygenate the ore unexposed to external air, or which would dissipate its volatile mixtures exposed to air, with a degree of certainty which, with a small share of attention, would preclude the possibility of the metal attracting more oxygen.

In the present mode of preparing iron-stones, too much is left to chance and the discretion of subordinate workmen. The surface of the piles, being always in contact with the open air, is frequently exposed to perforations from winds, especially in those parts where the layer of ignited coals comes in contact with the current: a hollow space is soon formed; the fuel, by means of the fresh air continually pouring in, becomes ignited to whiteness; the surrounding stone is immediately fused: should this aperture be joined by a similar communication from opposite sides of the fire, a degree of heat will be excited beyond what could have been conceived possible in this mode of burning, and oxygen be combined with a mass of stone in such an high proportion as to form a very considerable part of the whole weight. This is an accident which will take place even where order, regularity and experience are conspicuous; were it possible to avoid it by torrefying the iron-stone in that just temperature which has been formerly demonstrated as the most proper, uniting at the same time an equal degree of economy, it would contribute greatly to reduce to certainty and rule the operations of the smelting-furnace.

The extreme of fusing the materials and combining the iron with an extra portion of oxygen, is not the only evil which an accurate mode of torrefaction would avoid: the same train of casualty often affords a considerable portion of the stone not enough prepared, and some quite un-

touched by the fire. The effects produced by iron-stone in this state are exactly similar to those experienced in the former, arising from the same cause, but existing as the result of two opposite extremes.

I confess it is much easier to point out the faults of an established mode of practice, than to substitute one, which, though it might unite some superior advantages, yet might not combine an equal number upon an extended scale. I have frequently considered the subject, and have as often been impressed with the truth of its importance in the manufacturing of iron. At some future period I may submit to the manufacturers of iron a double method of preparing iron-stones for the blast-furnace; in which, certainty of operation would be obtained, and in the end most probably a degree of economy insured equal to that of the present mode.

I would effect this by exposing the iron-stone stratified with a small proportion of coals, in simply constructed ovens, entirely covered on the top, except a few small funnels to carry off the smoke and disengaged vapours; the ignition to be occasioned by a current of flame passing under a flue in the bottom of the furnace, and conveying combustion to the sub-stratified coals. As this operation could be conducted to a physical certainty by means of damping the furnace instantaneously, as soon as the vapour, &c. had ceased, or as soon as complete ignition had pervaded the contents, (the duration to be determined by the nature of the iron-stone,) the results in this case could at all times be depended upon, and the present irregular products avoided. A second method of depriving iron-stones of their volatile mixtures would be to expose them to a considerable degree of heat, in contact with the dust of pit-coal coaks—as being the most economical—shut up from the admission of external air. This would not only deprive them of their acid water, &c. but would also un-

fix most of the oxygen combined with the metal, and afford the iron nearly in a disengaged state. Both these methods, however, at the present time, want the sanction of approving practice, on an extensive scale, to render them useful, or worthy of universal attention.*

De-oxygenation of Iron-stones. This process has been long known in part, and its principles (so far as understood) applied by the metallurgist to deprive the ore, subjected to the assay-furnace, of its oxygen, in order that the metal might become revived. Its operation is however much more extensive than what has hitherto been conceived; and its results afford the most beautiful and interesting phenomena known in the art of manufacturing iron.

De-oxygenation in the case of iron-stones will admit of being divided into three distinct stages, all of which tend to the same final result.

1. That wherein iron-stone is found to have lost its water of crystallisation and continuity of fracture; to have assumed a greyish white colour, soft and pulverulent; and greatly specifically lighter than formerly, having lost from 2-5ths to 9-20ths of its original weight.

2. That stage wherein the pieces have assumed the state of malleability, and have again become firm and connected; wherein they brighten under the file; and, when subjected to the hammer, under various degrees of heat, receive impressions at pleasure, and draw into shape.

3. That stage wherein, by prolonging cementation, the pieces of iron-stone are found to have passed into the state of steel; possessing all its properties, though difficult to separate from the earthy parts, and preserve its quality; but which may be precipitated from the steelified ore by fusion, in the state of cast-steel, by means of the assay-furnace.

* This plan had been adopted, and *Jars* has given a plate of the oven. T. C.

These three distinct stages of de-oxygenation are produced by a continuation of the same cause to which all iron-stones may at pleasure be subjected. With primary ores, richer in iron, the results are more certain, ponderous, and much better suited to operate upon, for the production of good malleable iron and steel: these are almost universally capable of being de-oxygenated, for the production of both these modifications of the metal. I have met with no exception, indeed, but in the case of a few granulated Norwegian ores, a blue speckled Danish ore, a few Russian bog ores, and the Scotch ore of the island of Islay.

In the present paper I shall confine myself to a minute detail of the first stage of de-oxygenation; the second and third stages, as they more immediately belong to the manufacture of iron and steel, shall be fully considered in connection with this curious mode of manufacturing these states of the metal from ores without fusion, which, from its novelty and simplicity, deserves a thorough investigation of operation and principle.

De-oxygenation, by roasting, simply consists in exposing iron-stone or ore, stratified with coaly matter, such as the dust of pit-coal coaks, or the charcoal of wood unexposed to air, at a high temperature. The oxygen contained in the ore is taken up by the charcoal, and passed off in the state of carbonic acid; while the water, carbonic acid, &c. is evaporated by the heat. In proportion as the ore becomes cleared from these mixtures, the metal becomes more and more revived, approaching however to the state of malleable iron, though still interspersed with the original quantity of earthy parts united in the stone. By increasing the temperature, and continuing its duration, the particles of iron unite, and form themselves into fibres, which even when cold, may be twisted and bent a little; still however having the original quantity of earthy

matter almost invisibly interposed betwixt their interstices. If the heat is urged still further, the iron, now malleable, begins to take up a portion of the carbon from the charcoal, and the metal then commences its change toward steel.

During any part of the process, should air come in contact with the ore, by previously destroying the surrounding charcoal, an immediate oxydation of the iron takes effect, proportioned in its increase of weight to the stage of the operation at which it is effected. The ore has then passed into a friable, bulky, and unmetallic state.

In de-oxygenating iron-stones, with an intention of discovering and of establishing an analogy as to the quantity of oxygen contained in the respective classes of stones, I was frequently led to conclude, that argillaceous and calcareous iron-stones contained less oxygen than iron-stones where a greater proportion of silex predominated. Though by far the greater number of experiments performed on this subject were in favour of such an inference, yet I have at times experienced my arrangement palpably contradicted, without being able to solve the obtruding difficulty. I shall not however despair, in most cases, to reduce to certain invariable inherent properties, and external characteristic forms, the various iron-stones in the manner in which I have arranged them, and consonant to the results obtained from them in the process of manufacture. The utility of such an arrangement, founded upon experiment, must be obvious and striking: it will give certainty and value to the various products of the manufacturer, as it will in the end systematize the manufacture itself, and reduce it to rules guided by principle, and not by the aberration of a false or misinformed judgment.

From many experiments I have made with all the varieties of iron-stones found in this country, I shall subjoin the treatment of one of each class, highly marked with the predominating earths, that an accurate opinion may be formed of the phenomena exhibited in this part of the process.

I. I used a fine *argillaceous* iron-stone, in small pieces, weighing - - - - - 1750 grs.

After a proper distillation of 8 hours in a degree of heat equal to 30° of Wedgewood*, I obtained a fine purple-coloured fibrated iron-stone, which, when cold, weighed - 1160

Loss of water, acid, and sulphur, equal to 33·6 per cent. - - - - 590 grs.

The influence which the magnet possessed over this stone was considerable; the adhesion to the tongue was however great.

I next introduced into a proper vessel, in contact with charcoal-dust, some pieces fractured from the same original mass; they also weighed - - 1750 grs.

After exposure for 14 hours to a degree of heat equal to 120° of Wedgewood, the iron-stone, being carefully separated from the charcoal and dried, weighed - - 1002

Loss of water, acid, sulphur, and oxygen 748 grs.
Lost by simple distillation - - 590

Oxygen taken up by the charcoal, equal to 9 parts in 100 - - - - 158 grs.

This must not, however, be taken as the total measure of oxygen combined with the iron, but only that portion taken up in the first stage of the operation; which, as it possesses the following properties, fully entitles it to this distinction:

1. The iron-stone, from being firm and compact, possessing specific gravity from 3 to 3·5, now becomes comparatively light, friable, and pulverulent; specific gravity, from 2·1 to 2·5. It now moulders with a slight pressure, and is easily reduced to fine powder of a whitish grey colour, which again possesses the following distinct proper-

* Wedgewood's pyrometer.

ties : It adheres to the magnet in the greatest abundance, but not in confused clusters like iron-stone simply torrefied or roasted : a manifest indication to become attached in the form of fibres is visible ; and the quantity taken up is equal in point of bulk to the effect produced with iron filings.

2. Iron-stone in this state pulverised, when strewed in the flame of a fire or candle, gives out metallic sparks, like the combustion of iron-filings when strewed in the same manner. When the flame of the blow-pipe is directed upon it, a considerable inflammation takes place, and the metallic particles again become oxydated.

3. In this state, iron-stones possess the property of effervescing violently with the sulphuric and muriatic acids. The iron and lime are instantly dissolved, without the production of heat. This is only peculiar to iron-stones at this period of de-oxygenation. In no other state either raw or roasted, does iron-stone possess this property, unless highly united to lime ; but remains undissolved till it has attracted a portion of the oxygen from the acid with which it is in contact.

From these confirming circumstances I conclude, that the particles of metal exist in a highly disengaged state ; that they are partially malleable, yet so much combined with oxygen as to be easily precipitated, in fusion, for the production of cast-iron, with a sparing proportion of fuel, and a proper application of solvents. So far, therefore, as this experiment leads us, the practical analysis of this ore may be thus stated :

In the assay-furnace 100 parts of this iron-stone yielded

a button of super-carbonated crude iron equal to - - - - -		39·5 parts.
Water, carbonic acid, and sulphur, lost in simple distillation - - -		33·6
Oxygen taken up by the charcoal	9·0	

In the subsequent part of the operation I found that, when the iron-stone had assumed malleability, and brightened under the file, a further quantity of oxygen was taken up, equal to - - 4·2—13·2

Clay, lime and silex united in the stone - 13·7

100 parts.

The earths I found to be proportioned nearly as follows: Clay 7 parts, calcareous earth 4, silex 2·7 = 13·7.

II. Of a *calcareous* iron-stone, reduced in the same manner, I operated upon - - - 1750 grs.

After being exposed to a similar distillation, I found it to weigh - - - - 1090

Lost in water, acid, and sulphur, equal to 37·7 per cent - - - - 660 grs.

This iron-stone, when torrefied, exhibited a thin schistus of calcareous plates: its fracture also presented calcareous lines running in various directions: its colour was reddish brown, partially fibrated, magnetic, and tenacious to the tongue.

I took of the same, mixed with charcoal dust, 1750 grs. and exposed the vessel to a temperature equally high with the former.

The residue, when carefully separated from the charcoal, washed and dried, weighed 922

828 grs.

Lost in simple distillation, as formerly shewn, 660

Oxygen taken up by the charcoal, equal to 9·6 parts in 100 - - - - 168 grs.

In this state the stone was pulverulent, much frittered, and of a darkish grey colour. Its fracture exhibited a number of white spots like madrepore. In many places

lime was distinctly perceived: when pulverised, it sparkled in the flame, dissolved rapidly in acids with a violent effervescence, was less magnetic than the former, though possessing a great tendency to adhere in the form of fibres. From this treatment the practical analysis of this stone will stand as follows:

In the assay furnace it yielded, of super-carbonated crude iron, per cent. - -		37·5 parts
Water, acid, and sulphur lost, as formerly shewn, - - -		37·7
Oxygen taken up in the first stage of de-oxygenation - - -	9·6	
Afterwards taken up in cementing the iron-stone to render it malleable -	4·9	—14·5
Clay, lime and silex - - -		10·3
		100 parts

By dissolution in acids, I found the earthy parts to be nearly as follows: Lime 5·2—Clay 3·1—Silex 2=10·3.

This analysis must not, however, be taken as a standard whereby the quantity of iron and earth is to be judged of in calcareous iron-stones in general. The iron-stones of this class, contain much less iron than argillaceous or even siliceous iron-stones; 28 to 32 per cent. are products more commonly met with than 37 and upwards; the difference in point of metal being made up in lime and clay. In stating the quantity of oxygen disengaged, I conceived it proper to adduce iron-stones, though of different classes, yet containing nearly the same weight of metal as the quantity either disengaged or absorbed must be in a direct ratio to the existing quantity of iron.

III. I operated with a *siliceous* iron-stone, weighing also - - - - 1750 grs.
composed of small pieces, and exposed for the same length of time, and to the same

degree of heat as the former classes: the residue weighed - - - - 1249

Lost in volatile matter by simple distillation, equal to 28·6 per cent. - - 501

In its present state the fracture of this iron-stone was reddish brown, studded with spiculæ of shining silex, slightly adhesive to the tongue, and considerably obedient to the magnet.

I next introduced into a crucible, stratified with charcoal-dust, some pieces of the same mass, weighing - - - - - 2374 grs.
and exposed them to a degree of heat of equal intensity with the former; after the pieces were washed, and carefully dried, they weighed - - - - - - 1343

Amount of water, acid, sulphur, and oxygen dissipated - - - - - 1031 grs.

Equal to - - 43·4 parts in 100

Lost in simple distillation as above - - - 28·6

Oxygen taken up - 14·8

This iron-stone was frittered, very magnetic, but dissolved less rapidly in acids, and with less effervescence; colour of the fracture light grey, and slightly spongy. The practical analysis of this siliceous iron-stone will therefore stand thus:

Carbonated crude iron obtained in the assay furnace - - - - - 36 parts.

Water, acid, and a considerable portion of sulphur - - - - - 28·6

Oxygen taken up as above - 14·8

Further, as will hereafter be shewn

in making the iron-stone pass into a state of malleability - -	2·5—17·3
Earths, viz. silex 9, lime 6, clay 3·1, = -	18·1
	100 parts.

In these experiments I wished to obtain results which would throw light upon the de-oxygenation of iron-stones, with a view to apply them to practice upon an extended scale. I therefore used fresh ore, in order to present nearly the same surface to the action of the heat, and to be able to judge of the results apart from each other. In torrefaction, it frequently happens that the stone is reduced too small to enable us, by its subsequent treatment, to form a probable opinion of the tenacity, or otherwise, with which iron-stones hold their oxygen. The difference betwixt returning into the crucible the same pieces deprived of their volatile mixtures, and operating upon fresh ore, cannot be great, especially when they are selected from fragments of the same mass, directed by an intimate acquaintance and thorough knowledge of the qualities indicated by their external forms.

All iron-stones thus exposed to de-oxygenation become more or less saturated with carbon; it forms a union like carbon in steel, and its presence is only ascertained when the iron-stone is dissolved in an acid, by rising to the top, and forming a fine pellicle possessing lustre and various shades of colour. I have also at times detected crude carbon in the centre of pieces of ore one and a half inch diameter. To the remainder of this mixture, after the oxygen is taken up, ought to be attributed the natural tendency, which most malleable iron made in this process, has of becoming red-short.

The average of the results of the principal classes of iron-stones may serve for information on the products obtained, by treating those of equal quantities of mixture.

The analysis here furnished is not that of the chemist, or laboratory; but, though the calculations are less rigorous, yet they are sufficient for the manufacturer, and better suited for practical information; as they never once lose sight of their application and effects in the large way of manufacture, and as they have been chiefly effected by an agent, which alone, in the large way, can modify the whole, and procure results consonant to the use and existence of the metal.

From the amount of the experiments here recorded I would be apt to draw this conclusion, that, in general, iron-stones are variously combined with oxygen as to quantity: argillaceous iron-stone, least; calcareous, more; and siliceous iron-stones, most of all. *Mushet.*

In many places where the ore is too small to be conveniently roasted, it is washed to separate the dirt; but generally as I think, this washing is at the expence of a quantity of the yellow oxyd of iron which is at the same time washed away.

Of Fuel. Throughout the continent of Europe and America, the fuel is charcoal of wood. In Great Britain there were in the year 1806, 133 iron works at which 173 furnaces were in blast, producing annually 258,206 tons of iron. Of these, 11 iron works burnt the charcoal of wood; owing as I apprehend to the nature of the iron ore, such as the Cumberland and Lancashire ore, being what Mushet calls the primary iron ores. These 11 furnaces made annually 7800 tons of iron being on the average 709 tons per furnace. The other 122 works containing 162 furnaces in blast which were worked with the coak or charcoal of pitcoal, made annually 250,406 tons of iron, or 1546 tons per furnace; so that the furnaces worked with stone-coal produce annually in that country, more than twice as much iron as those worked with wood-coal.

Charcoal of wood, being almost the only fuel used for iron works or by blacksmiths in this country, the process of charring the wood is well known: but the following observations of Mr. Mushet, are worth attention.

Charred wood is almost universally used throughout the Continent, as fuel for the production of cast-iron. From its great abundance in the northern countries, the discovery of pit-coal would be deemed of little advantage for many years to come*. The extensive woods in Siberia and Sweden afford a constant supply of fuel to the numerous iron works in those countries. The necessary regulations which the respective governments of each country have thought proper to enact, will in all probability preserve, during their existence, the necessary supply of fuel for the manufacturers†. If the woods receive necessary care and attention after the first cutting, they will replace themselves at periods from 15 to 18 years. The charcoal used in Siberia is all made from the pine and larch, the country affording no other varieties of timber. In Sweden, the manufacturers are supplied with a considerable proportion of harder woods, which is greatly in favour of the manufacture.

It has already been noticed, in a former paper, that the fuel used in Britain at an early period, and so far down as the beginning of the present century, chiefly consisted of wood. The kinds of wood used for this purpose were

* Pit-coal has been discovered in Siberia of various qualities and in great abundance, fit for the same purposes to which it is applied in this country.

† In Sweden there is a law restricting the manufacturers of iron to a certain annual produce; and this quantity is always in proportion to the ground attached to the work. In this manner the wood is enabled to replace itself at certain intervals; and each work is insured of an annual, though moderate supply. The more extensive and unpeopled tracts of Siberia, render such exactitude in the execution of the laws less necessary.

various; but char of hard wood, such as oak, birch, ash, &c. &c. was always preferred to that made from pine, holly, sallow, &c. &c. At the small remaining number of charcoal furnaces now in this country, the oak has still the undoubted preference. Its firmness and continuity enable it in the blast-furnace to support and convey principle to the iron contained in a larger portion of ore, than charcoal made from softer wood. The same properties also enable it for a time to sustain a heavier pressure of air from the discharging pipe: this facilitates the reduction of the whole, and greatly augments the weekly produce in iron. The mode of preparing charcoal of wood for the blast-furnace, though extremely simple, is yet capable of being greatly misunderstood, so as to occasion a considerable waste of wood in the process. The following is the detail of an operation which I have seen successfully tried, and which was productive of excellent charcoal. It is the same I believe as is followed at the two charcoal furnaces in Argyleshire.

First of all, a plot of ground is raised a little higher than the surrounding surface: this is made slightly convex. The burner commences by placing in the centre a circle of sticks, transversely inclining, and crossing each other near their tops. Around these are built successive circles of wood of various sizes, from 1 to 10 inches diameter; but care is always taken to place those of similar diameters in the same circle. A round of beams, of the largest nature, is immediately followed by one so much smaller as to fill up the interstices between the larger diameters, that no more air may be admitted than is necessary to excite gradual combustion. These are again followed by pieces of an increasing diameter. This mode of ranging the large and small sizes is continued till such time as the pile is deemed sufficiently large. The total width may then measure from 20 to 30 feet. The last

layer is commonly composed of small brush-wood. The whole is then covered with turf, the grassy side towards the wood; a coating of earth is then applied all round the bottom of the pile, and firmly beat to prevent the unnecessary admission of air. A small funnel, or opening on the top, is preserved by the transverse position of the first layer of wood; this is generally about 18 inches deep, into which the burning fuel is introduced. Combustion is in this manner first conveyed to the top of the pile, and is continued by feeding the small craters with pieces of wood for 4 or 5 days. When the interior part of the fire next the top is deemed sufficiently kindled and spread over the whole diameter, a row of holes is opened a few inches below, each about two inches diameter. The hole at the top is then entirely shut up, and the fire, now completely spread, slowly descends to where the air is admitted by means of the small apertures. When this is observed by the burner, which is known by the disappearance of smoke and vapour, they are immediately shut up, and a second row opened 6 or 8 inches under the first. In this manner the fire is conducted to the foundation of the pile, and the whole mass exposed to proper combustion. The intention of the operation is to bring the whole pile to a state of complete ignition, but in such a manner that no greater a portion of it may undergo combustion than is necessary to produce that effect. Hence the necessity for guarding against too free an access of air during the process. As soon as the operation is ended, which may last for 10 or 14 days, the whole is more closely covered up, and kept so till such time as the char is deemed sufficiently cool to be fit for drawing: it is then separated from the earth, and carrried away in bags or in waggons. Those pieces of wood not sufficiently charred are by the workmen called *brands*, and are commonly used for fuel to the next fire.

The loss of weight in charring wood is inconceivably great. In the large way it is almost impossible to ascertain it to any degree of exactness. The qualities of wood are so various, and the tendency which some have beyond others of parting with their juices, even when exposed to the same temperature, render it at best but a matter of uncertainty. I shall however insert a few which I have charred in the small way, and the results obtained from them; before weighing they were all exposed to the same temperature for a considerable time, and thoroughly dried.

It is however worthy of remark, that the produce in charcoal in the small way, does not give an invariable standard whereby to judge of that obtained on a large scale, where ignition is caused by the admission of external air into contact with the wood. In the large way the quantity of char afforded will depend more upon the hardness and compactness of the texture of wood, and the skill of the workman, than on the quantity of carbon it contains. In the following tables I have simply expressed the existence of the alkaline principle, in the various ashes obtained from the combustion of 1 pound of wood avoirdupois weight: this may be of use to those who wish to make experiments upon the formation of pot-ash. It will also be observed, that there are some woods that yield a much larger proportion of carbon than oak: these, however, are either too scarce or two valuable to be applied to the manufacturing of iron in this country.

*Table of the component parts of one English pound avoirdupois, or seven thousand Troy grains of the following varieties of Wood.**

	Water, Hyd. gas, Carb. acid	Carbon	Ashes	Colour and Degree of Saturation of the Alkaline Principle.
Oak - - -	5382,6	1587,8	29,6	Grey, sharply alkaline.
Ash - - -	5688,2	1258,0	53,8	Whitish blue, do.
Birch - - -	5650,2	1224,4	125,4	Brownish red, do.
Norway Pine	5630,9	1344,3	24,8	Brown, not in the least alkaline.
Mahogany - -	5147,0	1784,4	68,6	Grey, sharply alkaline.
Sycamore - -	5544,0	1381,4	74,6	Pure white, weakly, do.
Holly - -	5524,4	1394,3	81,3	Do. sharply, do.
Scotch Pine -	5816,7	1151,9	31,4	Brown, perceptibly do.
Beech - -	5537,3	1395,9	66,8	Greyish white, sharply do.
Elm - -	5576,6	1370,2	53,2	Grey, partially do.
Walnut - -	5496,5	1446,4	57,1	Pure white, light as down, weakly do.
American Maple	5553,2	1393,1	53,7	Dark grey, sharply do.
Do. Black Beech	5425,9	1301,8	72,3	Brown, do
Laburnum - -	5196,4	1721,0	82,6	White and grey, partially alkaline.
Lignum Vitæ -	5083,0	1880,0	35,0	Grey, sharply do.
Sallow - - -	5626,0	1294,8	79,2	Light grey, do.
Chesnut - -	5341,3	1629,6	29,1	Grey, do.

Parts in 100.

	Water, Hyd. gas, Carb. acid	Carbon	Ashes	Colour, Nature, Compactness of the Charcoal.
Oak - - -	76,895	22,682	0,423	Black, close and very firm.
Ash - - - -	81,260	17,972	0,768	Shining black, spongy, moderately firm.
Birch - - -	80,717	17,491	1,792	Velvet black, bulky and do.
Norway Pine -	80,441	19,204	0,355	Shining black, bulky and very soft.
Mahogany - -	73,528	25,492	0,980	Tinged with brown, spongy, and firm.
Sycamore - -	79,200	19,734	1,066	Fine black, bulky and moderately firm.
Holly - - -	78,920	19,918	1,162	Dull black, loose and bulky.
Scotch Pine -	83,095	16,456	0,449	Tinged with brown, bulky but pretty firm.
Beech - - -	79,104	19,941	0,955	Dull black, spongy, but very firm.
Elm - - - -	79,655	19,574	0,761	Fine black, moderately firm.
Walnut - -	78,521	20,663	0,816	Dull black, texture close, body firm.
American Maple	79,331	19,901	0,768	Dull black, texture close, moderately do.
Do. Black Beech	77,512	21,455	0,033	Fine black, compact & remarkably hard
Laburnum - -	74,234	24,586	1,180	Velvet black, do.
Lignum Vitæ -	72,643	26,857	0,500	Greyish, resembles pit coal, coaks, do.
Sallow - - -	80,371	18,497	1,132	Velvet black, bulky, loose and soft.
Chesnut - -	76,304	23,280	0,416	Glossy black, compact and firm.

* Dr. Watson 1 Essays, 132, says that 106lb. of dry pealed oak, yielded 19 ounces of ashes: these ashes yielded 1 ounce and a quarter of saline matter. Hence 1 ton of potash requires about 1300 tons of dry, or about 1800 tons of green oak.

The advantages that charcoal possesses, beyond those of pit-coal, for the manufacturing of crude iron, are derived from the purity of its component parts, and the superior quantity of unalloyed carbon it affords to the iron. This principle is presented to the metal free from the combination of clay, lime, sand, and sulphur; with which pit-coal frequently abounds. A determinate quantity of charcoal by measure, will smelt and convey principle to three times the quantity of iron that can be done by the same measure of pit-coal coaks. Its greatest and most useful property, however, seems to be developed in the refinery fire, and similar bar-iron operations; where it manifests in the most evident manner its superiority over pit-coal, by shortening the tedious processes of the forge, diminishing the waste, and affording a much superior quality of iron for all the purposes of subsequent manufacture. Thus far Mushet.

Wood in charring loses somewhat of its bulk: by means of the heat applied, the acid moisture is distilled away, together with some part of the resinous and carbonic principle of the wood, but the woody fibres consisting chiefly of carbon or pure charcoal remain, and the vascular part now emptied of the fluid contents, form the pores of the charcoal. Of these Dr. Hook counted 150 in the eighteenth part of an inch in length; hence he concludes that in an inch square of charcoal there are 5,724,000 pores.

As there are great variations in the weight of wood, 1st. as to the kinds, 2dly. as to the time when it was cut, 3dly. as to the length of time it has been exposed to the atmosphere, 4thly. as to the part of the tree from which it is cut, no certainty can be obtained as to the proportion of charcoal by weight obtained from various woods: I think the charcoal according as it is well or ill burnt, varies from a third to a fifth of the weight of the dry wood from whence it was made.

In Pennsylvania a cord, (8 feet by 4 feet and by 4 feet, or 128 cubic feet of wood, put up as close as the sticks reasonably can be placed) of oak, will yield about 40 bushels of coal; a cord of pine, about 42 bushels: or it may be said that 100 bushels of wood coaled in the common way for the use of a furnace, will require two and a quarter cord of wood; but if coaled for a bloomery or refinery, where the coal must be all of the best quality, 100 bushels will require two and a half cord. The expence of cutting is about 40 cents a cord, coaling about 36 or 37 cents. From 20 to 40 cords of wood are coaled at once upon one hearth. The quantity of coal used to produce a ton of metal will of course vary with the nature of the iron ore, and the skill of the founder or manager. Mushet reckons 16 cwt. of charcoal of wood to a ton of metal; which I think is too little. In Pennsylvania I have heard it computed at 200 bushels, of about 14lb. to the bushel, of dry charcoal. There is no ascertaining any fact of this kind by weight; because, good well burnt charcoal will imbibe from the atmosphere in the course of 3 or 4 days, 12 or 13 per cent. of air and moisture: but on this calculation, the English (or rather the Scotch) managers make, a ton of iron with a fourth less coal than the American. Good charcoal should ring with a metalline sound: it will frequently strike fire with steel. Charcoal exposed to moisture, and kept together in great heaps, has been known to take fire spontaneously. I suspect charcoal is the worse for the moisture it imbibes; for in the heat of a furnace, the water will be decomposed both by the charcoal, and by the iron; and as water contains eighty-five and two thirds per cent. by weight of oxygen, and only fourteen and one third of hydrogen, it appears to me, that coal must be greatly wasted by moisture; but the subject is very difficult and complicated.

I have met with no calculations on which any reliance

can be placed of the time when an acre of ground from which the wood has been cut, will replace its original quantity: nor of the average cubic feet of wood on an acre. Mushet, conjectures these at 2000 cubic feet and 18 years; but the kind of wood, and the climate, and the soil, will make so much difference, that there is nothing like certainty. Pine in this country I imagine would replace itself in 16 years, chesnut in 12, oak in 20.

Of Pit-coal. The first intimation of the use of pit-coal for smelting, that I know of, is in Pryce's Mineralogy of Cornwall; but Becher early in the reign of Charles the 2nd proposed its use among the iron furnaces. The following brief history of its introduction is from Mushet, 7 Phil. Mag. 37.

The advantages which individuals derived from the manufacture of iron had induced many to engage in it. The business in point of extent seemed only limited to the supply of wood. New erections, for want of a proper supply of materials, became impracticable: those already engaged were more anxious to preserve their supply, however much circumscribed, than to listen to innovation, which, by substituting pit-coal for the charcoal of wood, would give to the new establishing manufacturer a great superiority in the market. It was also highly probable that many of the iron-works then established were at a considerable distance from pit-coal, the universal introduction of which would have proved fatal to their interests. Under such unfavourable circumstances, the discovery, or rather the practicability, of making pig-iron with pit-coal, we find announced by Simon Sturtevant, Esq. in the year 1612, who upon application, was favoured with a patent from king James for the exclusive manufacture of iron with pit-coal in all its branches for thirty-one years. In return, the said Simon Sturtevant bound himself to publish his discoveries, which afterwards appeared in quarto under the title of his *Metallica*.

It is uncertain from what reasons, but Mr. Sturtevant failed in the execution of his discoveries upon a large scale, and was obliged next year to render up his letters of monopoly.

The second adventurer in this line we find to have been John Ravenson, Esq. who, like Sturtevant, was successful in obtaining a patent for the new manufacture, but, like him also, was inadequate to the completion of it upon an extensive scale. Ravenson was also enjoined to publish his discoveries under the title of his *Metallica*, printed for Thomas Thorp, *anno* 1613. Several other adventurers stepped forth, all of whom had the mortification of resigning their patents without having contributed to the success of the arduous undertaking.

In 1619 Dudley obtained his patent, and declared, that although he made only at the rate of three tons of pig-iron weekly, he made it with profit. The discovery was perfected at his father's works at Pensent in Worcestershire. This gentleman's success in the various manufactures of iron with pit-coal had united not only all the proprietors of the charcoal iron trade, but many new adventurers, who wished to share in the emoluments of the new discovery. Their interest was so powerful as to limit Dudley's patent from 31 to 14 years. During the most of this period he continued to manufacture pig and bar-iron, and various castings, all of which he sold much lower than the charcoal manufacturers. In the article of castings alone, he must have had greatly the start of the charcoal foundries, as the quality of carbonated coak pig-iron is far superior to that of the charcoal iron of this country for the general purposes of casting.

The superior genius of Dudley was not always an object of passive indifference in the narrow estimation of the long established manufacturers. The envy occasioned by his uncommon success, produced at last a spirit of

combination, which terminated in a hostile attack upon his devoted works. His improved bellows, furnace, forge, &c. all fell a prey to a lawless banditti, betwixt whom and its furious leaders, no shades of distinction were visible, but those of avarice, ignorance, and the most contemptible prejudice.

To evade the mode of operation discovered by Dudley, or to introduce the making of pig-iron with pit-coal to greater advantage, a new plan was adopted by Captain Buck, Major Wildman, and others, in the forest of Dean, where they erected large air-furnaces, into which they introduced large clay pots, resembling those used at glass-houses, filled with various portions of the necessary mixture of ores and charcoal. The furnaces were heated by the flame of pit-coal, and it was expected that, by tapping the pots below, the separated materials would flow out. This rude process was found entirely impracticable; the heat was inadequate to perfect separation, the pots cracked, and in a short time the process was abandoned altogether.

The misfortunes which successively befel the unfortunate Dudley, arising from rivalship in the iron business, and his attachment to the royal cause during the civil wars, prevented his improvements from being closely followed up. The refusal of a new patent after the restoration prevented him from again entering into the business with his usual enterprise. From that period till about the year 1740, nothing of importance was done in the manufacture of coak pig-iron. The application of the steam-engine for raising and compressing air, no longer confined the manufacturer to local situations. Larger furnaces, with a proportionate quantity of blast, were introduced. Among the first effects, from 8 to 10 tons of pig-iron were produced weekly. Ever since, the weekly quantity has in general been increasing. The produce

being considerably dependent upon the quantity of air used for reduction, it is now so well understood, that at some works the blowing-machine is calculated to produce frequently 40 tons of melting pig-iron *per* week at each furnace. At some iron-works in Wales, where oxygenated crude iron is manufactured purposely for converting into bar-iron, there are several instances of a furnace producing 70, 71, and 72 tons of metal weekly. This astonishing quantity forms a most striking contrast with the early exertions of Dudley, who conceived three tons a profitable produce, and whose greatest exertions never exceeded 7 tons of pig-iron weekly.

After this slight sketch of the progress of manufacturing pig-iron with pit-coal, it may be gratifying to make a few observations upon the process conducted with the charcoal of wood. The superior purity of the carbonaceous matter in wood, and its greater degree of inflammability, render this operation more simple than that performed with pit-coal. The former properly admitted of a small furnace being used; and also required a much less degree of blast to purify the ore, and give out satisfactory results both in the quantity and quality of the metal. Few charcoal furnaces exceeded the height of 20 feet, and many of them were from 12 to 15. A very small column of blast was necessary to excite ignition, and produce the reduction of the materials. Lancashire and Cumberland ores were chiefly in use; their superior richness in iron rendering them soon metallised when in contact with ignited charcoal of wood: 12 to 24 hours were sufficient for this purpose, according to the size of the furnace and the quality of the pig-iron wished. Not so in the manufacturing of coak pig-iron at present: the inferior quantity of iron which is contained in iron-stones, the impurity of the carbonaceous matter in pit-coal, establishes a much less degree of affinity betwixt the metal and

the principle of its reduction. The oxygen of the iron-stone is longer in being removed: this requires an additional period of contact. To procure this, the furnace must be heightened to 35 or 40 feet, and the descent of the materials protracted to three days.

It will be proper to exhibit the comparative effects produced by the char of pit-coal and that of wood. The following particulars will serve as data to make a calculation of the relative effects of the two different fuels with a charcoal furnace of 26 or 27 feet high, 9 feet wide at the boshes, and blown by two inch and three quarter pipes placed along side of each other at the tuyere of the furnace. To make forge-pigs with this furnace, the following proportions have by experience been found requisite for each charge:

2 sacks of charcoal of 112lb. each -	224lb.
7 measures of well dried Lancashire ore, each 112lb.	784
Raw iron-stone - - - -	56
Limestone - - - - -	14

In 24 hours 18 of the above charges would have been consumed, and nearly 3 tons of forge-pigs produced.

The total quantity of char used for the quantity would be - - -	$2 \times 18 =$	36 cwt.
The total quantity of iron ore - -	$7 \times 18 =$	126
——— of iron-stone -	$\frac{1}{2} \times 18 =$	9
——— of limestone -	$\frac{1}{8} \times 18 =$	$2\frac{1}{2}$

We find therefore that 12 cwt. or 1344lb. of the charcoal of wood, produces of forge pig-iron 2240lb. or 1 ton; and that 126 cwt. of Lancashire ore + 9 cwt. of iron-stone, yielded of metal 60 cwt. This quantity, by an easy mode of calculation, will be found to be at the rate of 44·4 *per* cwt.

When carbonated crude iron was produced, the charge was, 200 cwt. of wood char, 5 cwt. of ore, 1-2 cwt. of iron-stone, 14 lb. of limestone.

The weekly quantity was always diminished in pro-

portion to the reduction of the quantity of ore used. In 24 hours the quantity of the pig-iron produced, averaged 48 cwt. of carbonated crude iron. As this is the quality of metal which serves as the basis of the calculation in Number XX. of the Philosophical Magazine, it will be the most proper standard to compare the widely different effects produced by wood and pit-coal. In that Number a table is given of the quantities of crude iron each variety of coaks produce, and which, for the sake of immediate comparison, I shall here again insert.

1 ton, or 2240lb. clod-coal coaks produces of carbonated iron - - -	1040lb.
1 ton, or 2240lb. splint-coal coaks -	840
——— 2240 mixed coals - -	702
1 ton, or 2240lb. of charcoal of wood, according to the proportions furnished above, will produce of carbonated iron	2986
1 ton, or 2240lb. of the same, will produce of oxygenated crude iron for forge-pigs - - - - -	3718; and
1 ton of carbonated pig-iron will require of the coaks of clod-coal - -	4824·6lb.
———————— splint-coal -	5973·3
———————— mixed - -	7147·5
———————— wood charcoal -	1680

From this comparative view it is found that charcoal of wood produces triple effects, or carbonates three times the quantity of crude iron that the clod-coal coaks do; three and a half times as much as the splint; and four and a half times as much as a mixture of free and splint.

The next consideration is the price of the two fuels. Charcoal of wood, about forty years ago, sold at 2*s.* 6*d.* *per* sack of 1 cwt. or 50*s.* *per* ton. 1 ton of good splint-coal coaks will be prepared on many of the present iron-work banks, labour included, at 11*s.* and at some places

so low as 10*s*. At present (1800) the price of charcoal is upwards of 4*l*. *per* ton. So that at this period, although the effects of wood are three and a half times those of splint-coal coaks, yet the price of one ton of charcoal wood will purchase eight tons of coaks; the quantity of the former limited to, and produced from, land which might be better applied to the purposes of agriculture; the latter found in immense fields, and in tracts of country which are always augmented in value by the developement of their mineral treasure.

A charcoal blast-furnace which smelts the whole year round, and occasionally makes forge-pigs and carbonated iron to the amount of 1000 tons annually, will consume 14,000 sacks of charcoal; which may be estimated at 1 cwt. *per* sack, or 700 tons, or 1,568,000lb. This divided by 18.75lb*. the pounds in a cubic foot, gives for the quantity of timber in cubical feet, 83.626. This is going upon a former calculation, and is supposing the wood to shrink but little during the process of charring. In the present state of the woods which are attached to iron-works, one acre will not yield more than 1200 cubical feet of timber. To ensure the annual supply, $\frac{83626}{1200} = 69.69$ acres of land would require every year to be cleared, or nearly 1400 acres would be requisite to form, with proper care, an unfailing source of supply; and at the rate of 4l. *per* ton, the fuel would cost 2,800l.

Let this be compared with a blast-furnace manufacturing the same quantity and quality of coak pig-iron. The average quantity for each ton will be nearly six tons of splint, or, as they lose 50 *per cent*. in charring, 3 tons of coaks × 1000 tons of pigs = 3000 tons of coaks, which at the highest price stated, 11s. *per* ton, amounts to 1,650l. or less than the charcoal, 1,150*l*. 6000 tons of splint-

* According to Watson, water being 1, dry oak is ,892. T. C.

coals will be easily procured from *one* acre of measurement where the stratum measures four and a half to five feet thick. An observation strikes us forcibly here, that, great as the consumption of wood is, a sufficient extent of country can from time to time replace any given quantity. No facts, however, which have hitherto come under our observation, warrant us to suppose the re-formation of pit-coal.

In preparing pit-coal for the blast furnace, well understood among manufacturers by the term *coaking*, flat surfaces are appropriated. These are firmly beat and puddled over with clay, so as to pass the necessary cartage without furrowing or loosening the earth. These spaces form squares, more or less oblong, and are called hearths; upon which the pieces of coal are regularly placed inclining to each other. Great care is taken to place each piece upon the ground layer on its acutest angle, in order that the least surface possible may come in contact with the ground. By this means, large interstices are preserved for the admission and regular communication of the air necessary to excite and effect complete ignition.

The quantity of coaks charred in one heap or hearth, is various at different, and even at the same works. Forty tons of coals is amongst the smallest fires, and some hearths again will admit of 80 or 100 tons. The length of the fire is in proportion to the quantity of coals built: the breadths and heights are also subject to no determinate standard; but are from 30 to 50 inches high, and from 9 to 16 feet broad. In building each fire, they reserve a number of vents reaching from top to bottom, into which the burning fuel is introduced. This is immediately covered by small pieces of coal beat hard into the aperture: these repress the kindling fire from ascending, and oblige it to seek a passage by creeping along the bottom, which is

most exposed to air. In this progress the fire of each vent meets, and, when united, rise gradually, and burst forth on all sides at once.

If the coal contains pyrites*, the combustion is allowed to continue a considerable time after the disappearance of smoke; the sulphur then becomes disengaged, and part of it is found in flowers upon the surface of the heap. If the coal is free from this hurtful mixture, the fire is covered up in a short time after the smoke disappears; beginning at the foundation, and proceeding gradually to the top.

The length of time necessary to produce good coaks depends upon the nature of the coal to be coaked, and the state of the weather. In 50, 60 to 70 hours the fire is generally completely covered over with the ashes of char formerly made: the coaks, thus entirely secluded from air, soon cool, and in 12 or 14 days may be drawn and wheeled to the furnace.

It is with pit-coal, in a great measure, as with wood, in the process of charring. Coals do not always afford a weight of coaks in proportion to the quantity of carbon in the coal. It depends more upon the capability of the coal to resist the waste occasioned by combustion, supported by external air, than upon the real quantity of carbon inherent in the coal; as may be seen by comparing the loss of weight which coals undergo in the large way, and the results obtained from the same coals, by burning them unexposed to external air in the small way.

The loss sustained in coaking coals fit for the purpose of manufacturing, or smelting iron, is found to be nearly as follows:

2240 pounds of free coals	- yield	700lbs. coaks,	loss 1540lbs.
2240 - - of splint and free coal mixt		840lbs. coaks,	loss 1400lbs.
2240 - of splint slightly mixt	yield	1000lbs. coaks,	loss 1240lbs.
2240 - - of pure splint	- -	1100 - -	loss 1120lbs.

* Iron combined with sulphur. T. C.

This great weight thus lost is chiefly carried off in smoke. If a vessel is placed, filled with cold water, in the midst of one of these massy columns of vapour, before the fire has penetrated to the surface of the heap, a considerable quantity of tar will condense upon its external surface: this will continue to increase till such time as the water assumes the temperature of the smoke. At many iron works from 300 to 1000 tons of coals are thus weekly reduced to cinder. What a prodigious quantity of bituminous vapour, surcharged with tar, ammoniac and oil, must for the present be lost ! !† (Mushet.)

Pitcoal contains always an empyreumatic oil, moisture, carburetted hydrogen or coal gas, and ashes; and frequently sulphur. The quantity of oil, moisture, and gas can be ascertained by distillation; the quantity of incombustible matter or ashes, by burning the coal in contact with air; the quantity of saline matter in the ashes by lixiviation, filtration and evaporation. The quantity of combustible matter in coal, can be found out by reducing 100 grains into powder, also 100 grains of pure salt petre into powder: throw by small quantities (a grain or two) at a time, first the coal, and immediately after the salt petre into a red hot crucible. The salt petre will deflagrate while there is any inflammable matter to decompose it; when the deflagration ceases, the quantity of inflammable matter may be determined by the quantity of salt petre employed. Lampblack may be used as a standard, for it contains of ashes not more than one part in about 250. The ashes in coaks vary from 3 to 45 per cent. Hence it is manifest that the coal meant to be employed ought to be analysed before they are used; to ascertain 1st. what quantity of coak can be obtained from a certain weight of coal: 2ly. what quantity of ashes or incombustible mat-

† This is the basis of Lord Dundonald's patent for collecting coal tar. Becher as early as the reign of Ch. 1st. had suggested the propriety of saving these products. T. C.

ter the coaks contain: 3ly. what quantity of carbon they contain. Argillaceous and siliceous iron-stone require more fuel than the calcareous kind. Some calculations of Mushet tend to shew that upon the average of iron-stones when roasted, 1 cwt. of the stone will require 1 cwt. of well burnt coaks, and that every ton of iron produced, consumes upwards of 2 1-2 ton of good coaks, and 672,000 cubic feet of atmospheric air, at 300 cubic feet per lb. of Iron. 5 Ph. Mag. 366. Doubtless the wetter the ore is, and the damper the cinder is, the more coal is wasted. 1 lb. of well burnt coaks when laid in water, will take up nearly two ounces of water in an hour's time: this will require additional fuel to evaporate it; but that is not all; for as water contains so very large a proportion of its bulk of oxygen (upwards of 85 per cent.) it is manifest that this oxygen or the greater part of it, will combine with, and waste its due proportion of carbon or charcoal, and form carbonic acid gas, which requires in its formation 28 3-4 per cent. of carbon. I say the greater part of the oxygen of the water; because one part of it, will be employed in forming carburetted hydrogen with the hydrogen of the water, and burn away. Still the waste, as it seems to me, must be very great.

It is manifest also, that the heat given out is not (other things being equal) exactly in proportion to the quantity of carbon in the fuel. Thus, I have generally understood that the charcoal of oak gives more heat than the charcoal of pine, but by Mr. Kirwan's experiments the proportion of inflammable matter in pine charcoal, is beyond that of oak. Grains of charcoal necessary to alkalize 100 grains of nitre.

Charcoal.	*Specific gravity.*	*Number of grains.*
Of oak	,332	32½
Of birch	,542	22
Of pine	,280	24½
Of fir	,441	27
Of pitcoal	,744	19

Coak Ovens. As the success of several manufactures depends on the procuring good coak, I feel pleasure in having it in my power to furnish a description of the kind of oven made use of in the north of England for coaking the refuse small-coal, which, before the adoption of this method, was entirely useless.

At the duke of Norfolk's colliery near Sheffield, several of these ovens are built on the side of a hill, occupying spaces formed within the bank. Each oven is a circular building, 10 feet in diameter within, and the floor laid with common brick set edgeways. The wall of the oven rises 19 inches perpendicular above the floor, and the whole is then covered with a brick arch which rises 3 feet 5 inches more, forming nearly a cone, whose base is 10 feet, and whose apex is 2 feet, if measured within. This opening of 2 feet at the top, is left for the convenience of supplying the oven with coal, and to serve as a chimney during the process. The whole height of the building from the floor is five feet, and the wall, which is 18 inches in thickness, is built with good brick, and closely laid, that no air may get in through any part of the work.

The floor is elevated three feet above the ground, for the convenience of placing a carriage under the door-way to receive the coak as it is raked from the oven. When the oven is thus finished, a strong perpendicular wall of common unhewn stone is thrown round it, of about 20 inches in thickness, and carried up the whole height of the oven, forming a complete square. The four corners between the circular building, and these outward walls, are then filled with soil or rubbish, and well rammed to give greater firmness to the work, and the more effectually to exclude atmospheric air.

When these ovens are once heated, the work goes on night and day without interruption, and without any further expense of fuel. It is conducted thus:—Small re-

fuse coal is thrown in at the circular opening on the top, sufficient to fill the oven up to the springing of the arch; it is then levelled with an iron rake, and the door-way built up with loose bricks. The heat which the oven acquires in the former operation is always sufficient of itself to light up the new charge; the combustion of which is accelerated by the atmospheric air that rushes in through the joints of the loose bricks in the doorway. In two or three hours the combustion gets to such a height, that they find it necessary to check the influx of atmospheric air: the doorway is therefore now plastered up with a mixture of wet soil and sand, except the *top* row of bricks, which is left unplastered all night. Next morning (when the charge has been in 24 hours) this is completely closed also; but the chimney remains open till the flame is gone, which is generally quite off in 12 hours more; a few loose stones are then laid on the top of the chimney, and closely covered up with a thick bed of sand or earth. All connexion with the atmosphere is now cut off, and in this situation the whole remains for 12 hours, to complete the operation. The doorway is then opened, and the coaks are raked out into wheelbarrows, to be carted way. The whole takes up 48 hours; and as soon as the coaks are removed, the ovens are again filled with coal for another burning. About 2 tons of coals are put in for each charge. These coaks are ponderous, extremely hard, of a light grey colour, and shine with metallic lustre. They are used in those manufactures that require an intense heat.

When coak is required to be more of the nature of charcoal, the process is conducted in a different manner. The small coal is thrown into a large receptacle similar to a baker's oven, previously brought to a red heat. Here the door is constantly open, and the heat of the oven is sufficient to dissipate all the bitumen of the coals, the dis-

engagement of which is promoted by frequently stirring with a long iron rake. The coak from these ovens, though made with the same kind of coal, is very different from that produced by the former operation; this being intensely black, very porous, and as light as pumice-stone. I am indebted to Mr. Curr, steward to his Grace the Duke of Norfolk, for these particulars, who very politely attended me through the works in the year 1802, and assisted me in taking the necessary measurements, &c. Parke's Chem. Cat. 4th ed. p. 443.

Dr. Watson (2 Essays, 318, et seq.) mentions the following results of a distillation of 90 ounces of Newcastle coal (bituminous) dry oak, box, mahogany and sallow wood.

	Newcastle coal.	*oak.*	*box.*	*mahogany.*	*sallow.*	*produce.*
oz.	12	37¼	61½	33½	48	Liquid
	56	30	26½	27½	20½	Charcoal
	28	28¾	8	35	27½	Loss in air.

In all cases the nature of the liquid, of the charcoal, and the loss, is nearly alike. The liquid consists, 1st. of an oily matter swimming at the top: 2dly. of an acid watery fluid. In France, this liquor has been converted into vinegar, when procured from wood. Dr. Bollman, of Philadelphia, has succeeded in repeating the experiment. 3dly. a more heavy tenacious oil. The liquor procured from the distillation of pit-coal, has a stronger odour, is more empyreumatic than that from wood. The air in both cases, is carburetted hydrogen, or the modern coal gas. Four ounces of Liverpool coal yielded me 19 quarts of this gas; 4 oz. of fine saw dust, yielded somewhat above 12 quarts. These facts, with the additional ones of the manifest transition from perfect wood to perfect coal in the same piece, as I remember to have seen at Whitehaven, leave no doubt in my mind, of coal having been originally wood. The turpentine (or spirits of tur-

P

pentine) from coal tar, though offensive when smelt, has on that account a very beneficial effect against worms, when used for paying of the bottoms of ships.

Pit-coal, *usually* produces more than the same bulk of coak or cinder, when not over burnt; but the weight is greatly diminished: Dr. Watson had a ton of coal coaked in the usual way, and it weighed when cold, 11 cwt.*

The coak of pit-coal (that is, the charcoal of stone-coal) cannot as I think be well made unless out of bituminous coal, that burns with a flame and smoke and runs to a light grey-black cinder of a silvery lustre. This cinder yields greatly more heat than the charcoal of wood; for 14lb. of brass that took an hour and a quarter to be melted in a portable furnance with *charcoal*, was melted with *coak* in 48 minutes. But it is apt to run together, before it is entirely consumed by the supply of air. Hence among other reasons, in England, all the furnaces have gradually increased their blast.

I have thus dwelt upon pit-coal or stone-coal as a fuel, because I foresee the time approaching when this substance must be resorted to in Pennsylvania. Of stone-coal there are two principal varieties; 1st. Bituminous coal that may be converted into a coak cinder, which burns with smoke and flame and soot; 2dly. Anthracite, or coal that burns with a slight blue lambent flame, without smoke or soot, and which is gradually converted into a white ash as its surface consumes. The first kind is found at Chingleclamoose and Sinnamahoning on the west branch of Susquehanna, and abounds throughout the whole of Pennsylvania in a line directly west of those places, and north and south of that west line: Pittsburgh seems to be almost in the centre of the coal district.

The anthracite, or second kind of coal, is found on the head waters of the Lacawana and Lehigh that run into the

*I find by recent trial, that a bushel of pine charcoal weighs 14½lb: of oak 22lb. T. C.

north east branch of Susquehanna. It is found in almost the whole of the country watered by those two rivers and their tributary streams: Wilkesbarre is in the centre of a large district of this coal, which extends southward across the Berwick turnpike road, and subtends the whole clay state formation between Sunbury and Reading. It is found near the river five miles below Sunbury; it is found a mile from the turnpike road near the 21 mile stone from Sunbury to Reading, and it is found on the heads of Schuylkill. It is the same with the culm of Wales, and the smokeless coal of Kilkenny. I think there are coal strata, of one kind or other, throughout one third part of the whole state of Pennsylvania. The coal district of Potowmack I am not acquainted with; what I have mentioned, I have in a great measure personally traced. Considering the infinite importance of this substance as a fuel, I think I may venture to say, that nature has formed the greatest part of Pennsylvania for a manufacturing country.

Of the Blast Furnace. This furnace resembles *externally* a truncated quadrilateral pyramid of considerable height in proportion to its thickness: it is built of the strongest masonry, with contrivances by means of flues to obviate the danger of its cracking by the expansion that takes place when it is heated. The interior of the furnace consists of the five following parts, reckoning from the bottom upwards.

First the *hearth*, composed of a single block of quartz grit about two feet square: upon this is erected what in France and Germany is called the *crucible*, which is a four-sided cavity six feet six inches high, slightly enlarging upwards so as to be two feet six inches square at the top: the part above, called the *boshes* is in the shape of a funnel or inverted cone, eight feet in perpendicular height, and twelve feet in diameter at the top: this terminates in the

cavity of the furnace which is of a conical figure, thirty feet high, and three feet diameter at the top; from this part it enlarges into a funnel shaped *chimney* about eight feet high and sixteen in diameter at its mouth. The lining from the hearth to the top of the boshes is composed of large blocks of quartz grit, and that of the cavity of the furnace is formed of fire bricks 13 inches long, and three inches thick. About two feet above the hearth is a round aperture called the *Tuyere*, (Tweer) made in one of the sides of the crucible to admit the extremity of the blast pipe, through which the air in a high state of compression is forced into the furnace; and at the bottom of the crucible is an aperture through which the scoriæ and melted metal are from time to time discharged. A furnace of this construction, if it meets with no accident, may be kept in constant work for three years or more, without requiring any repairs.

The furnace is charged at the chimney by regular intervals with coak, iron ore, and limestone in the proportion of about 4 of the first, 3 1-3 of the second, and 1 of the third, by weight, care being taken so to regulate the frequency of the charges, as that the furnace shall be always full nearly to the top of the great cavity. The density of the blast and the form of the discharging pipe are ordered so that the chief focus of heat is about the bottom of the boshes; hence the ore has to descend about 38 feet perpendicular, before it arrives at the place where the fusion is effected. This does not happen in less than 48 hours, so that the ore is all this time in a state of cementation at a high temperature in contact with the burning fuel, and in consequence is almost saturated with carbon when it reaches the hottest part of the furnace. Being arrived at this place, the limestone flux, and the earthy particles of the coaks and ore run down into a slag, the iron is also melted and more or less decarbonized, and in part oxyda-

Modern English Iron Smelting Furnace.

Fig. 3.

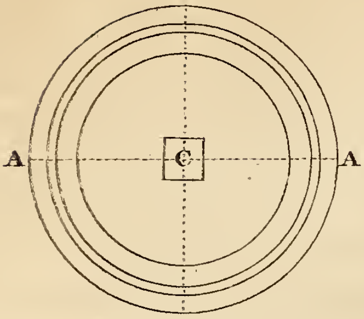


Fig. 4.

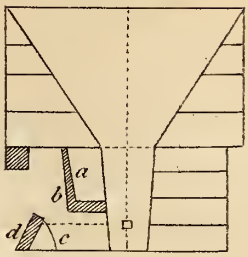


Fig. 1.

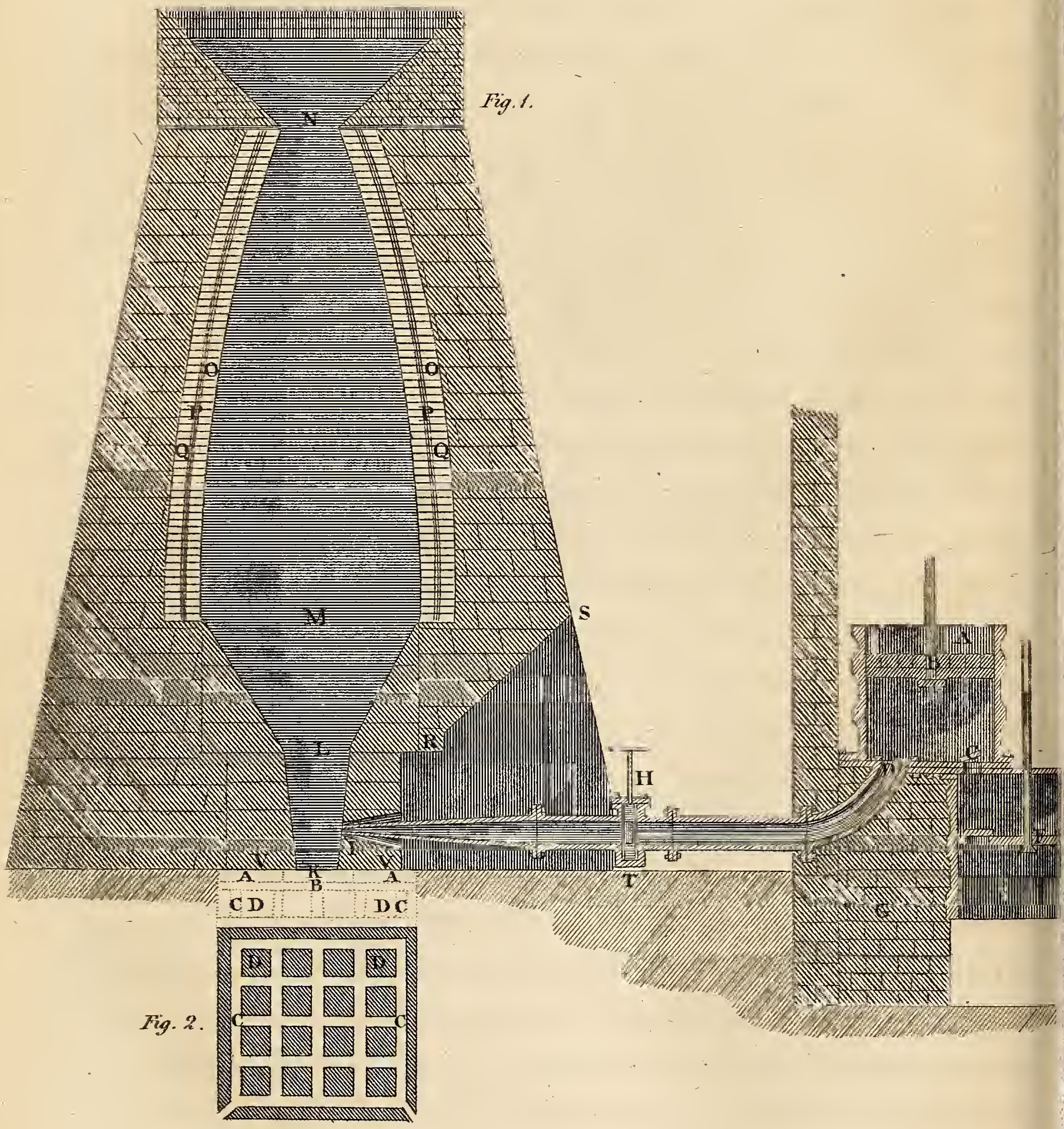


Fig. 2.

C. Tiebout sc.

ted by the blast inversely according to the proportion of fuel with which it is mixed (for the oxygen of the air by preference unites with the loose carbon of the coaks, rather than with that which has combined with the iron). The fluid mass soon sinks down below the influence of the blast, and while it remains in quiet at the bottom of the furnace the globules of iron are precipitated from the slag in which they were enveloped, and occupy the lowest place, while the covering of scoriæ thus interposed between the metal and that portion of the blast which is reflected downwards, prevents it from suffering any further loss of carbon. In proportion as the melted matter accumulates, the Sag being the uppermost, flows out at the aperture made for this purpose, and the iron is let out at regular intervals into furrows made in sand, where it forms what is called pig iron, or into a large reservoir whence it is poured by means of ladles into moulds, forming all the various articles of cast iron ware, from cannons and steam engine cylinders, to fire grates and common iron pots. (Aikins.)

Figure 1, (Plate 1.) represents a blast-furnace, with part of the blowing-machine. (Mushet.)

A, the regulating cylinder, eight feet diameter and eight feet high.—B, the floating piston, loaded with weights proportionate to the power of the machine.—C, the valve, by which the air is passed from the pumping cylinder into the regulator: its length 26 inches, and breadth 11 inches.—D, the aperture by which the blast is forced into the furnace. Diameter of this range of pipes 18 inches. The wider these pipes can with conveniency be used, the less is the friction, and the more powerful are the effects of the blast.—E, the blowing or pumping cylinder, six feet diameter, nine feet high: travel of the piston in this cylinder from five to seven feet *per* stroke.—F, the blowing piston, and a view of one of the valves, of which there are sometimes two, and sometimes four, distributed over the sur-

face of the piston. The area of each is proportioned to the number of valves: commonly they are 12 to 16 inches.—G, a pile of solid stone building, on which the regulating cylinder rests, and to which the flanch and tilts of the blowing cylinder are attached.—H, the safety-valve, or cock: by the simple turning of which the blast may be admitted to, or shut off from the furnace, and passed off to a collateral tube on the opposite side.—I, the tuyere, by which the blast enters the furnace. The end of the tapered pipe, which approaches the tuyere, receives small pipes of various diameters, from two to three inches, called *nose pipes.* These are applied at pleasure, and as the strength and velocity of the blast may require.—K, the bottom of the hearth, two feet square.—L, the top of the hearth, two feet six inches square.—KL, the height of the hearth, six feet six inches.—L, is also the bottom of the boshes, which here terminate of the same size as the top of the hearth; only the former are round, and the later square.—M, the top of the boshes, 12 feet diameter and eight feet of perpendicular height.—N, the top of the furnace, at which the materials are charged; commonly three feet diameter.—MN, the internal cavity of the furnace from the top of the boshes upwards, 30 feet high.—NK, total height of the internal parts of the furnace, 44 1-2 feet. —OO, the lining. This is done in the nicest manner with fire-bricks made on purpose, 13 inches long and three inches thick.—PP, a vacancy which is left all round the outside of the first lining, three inches broad, and which is beat full of coak-dust. This space is allowed for any expansion which might take place in consequence of the swelling of the materials by heat when descending to the bottom of the furnace.—QQ, the second lining, similar to the first.—R, a cast iron lintel, on which the bottom of the arch is supported.—RS, the rise of the arch.—ST, height of the arch; on the outside 14 feet, and 18

feet wide.—VV, the extremes of the hearth, ten feet square. This and the bosh stones are always made from a coarse gritted freestone, whose fracture presents large rounded grains of quartz, connected by means of a cement less pure.

Figure 2 represents the foundation of the furnace, and a full view of the manner in which the false bottom is constructed.

AA, the bottom stones of the hearth. B, stratum of bedding sand. CC, passages by which the vapour, which may be generated from the damps, are passed off. DD, pillars of brick. The letters in the horizontal view, of the same figure, correspond to similar letters in the dotted elevation.

Figure 3, AA, horizontal section of the diameter of the boshes, the lining and vacancy for stuffing at M. C, view of the top of the hearth at L.

Figure 4, vertical side-section of the hearth and boshes; shewing the tymp and dam-stones, and the tymp dam-plates. *a*, the tymp-stone. *b*, the tymp-plate, which is wedged firmly to the stone, to keep it firm in case of splitting by the great heat.—*c*, dam-stone, which occupies the whole breadth of the bottom of the hearth, excepting about six inches, which, when the furnace is at work is filled every cast with strong sand. This stone is surmounted by an iron plate of considerable thickness, and of a peculiar shape, *d*, and from this called the dam-plate. The top of the dam-stone and plate is two, three, or four inches under the level of the tuyere hole. The space betwixt the bottom of the tymp and the dotted line is also rammed full of strong sand, and sometimes fire-clay. This is called the tymp-stopping, and prevents any part of the blast from being unnecessarily expended.

The square of the base of this blast-furnace is 38 feet; the extreme height from the false bottom to the top of the crater is 55 feet.

The furnace being finished, the bottom and sides of it, for two feet up the square funnel, receive a lining of common bricks upon edge, to prevent the stone from shivering or mouldering when the fire comes in contact with it. On the front of the furnace is erected a temporary fire-place, about four feet long, into the bottom of which are laid corresponding bars. The side-walls are made so high as to reach the under surface of the tymp-stone; excepting a small space, which afterwards receives an iron plate of one and a half inch thickness, by way of a cover: this also preserves the tymp-stone from any injury it might sustain by being in contact with the flame. A fire is now kindled upon the bars, and is fed occasionally with small coals. As the whole cavity of the furnace serves as a chimney for this fire, the draught in consequence is violent, and the body of heat carried up is very considerable. In the course of three weeks the furnace will thus become entirely free from damp, and fit for the reception of the materials: when this is judged proper the fire-place is removed, but the interior bricks are allowed to remain till the operation of blowing commences. Some loose fuel is then thrown upon the bottom of the furnace, and a few baskets of coaks are introduced; these are allowed to become thoroughly ignited before more are added. In this manner the furnace is gradually filled; sometimes entirely full, and at other times five-eigths or three-fourths full. The number of baskets full depend entirely upon the size of the furnace: that in the plate will contain 900 baskets. If the coal is splint, the weight of each basket-full will be nearly 110lb. $\times$ 900 = 99,000lb. coaks. As this quality of coaks is made with a loss of nearly 50 *per cent.* the original weight in raw coals will be equal to 198,000lb. When we reflect that this vast body of ignited matter is replaced every third day, when the furnace is properly at work, a notion may be formed of the im-

mense quantity of materials requisite, as also the consequent industry exerted to supply one or more furnaces for the space of one year.

When the furnace is sufficiently heated throughout, specific quantities of coak, iron-stone, and blast-furnace cinders are added: these are called charges. The coaks are commonly filled in baskets, which, at all the various iron-works, are nearly of a size. The weight of a basket, however, depends entirely upon the nature and quality of the coal, being from 70 to 112lb. each.* The iron-stone is filled into boxes, which, when moderately heaped, contain 56lb. of torrefied iron-stone; they often exceed this when the stone has been severely roasted. The first charges which a furnace receives, contain but a small proportion of iron-stone to the weight of coaks: this is afterwards increased to a full burden, which is commonly 4 baskets coaks, 320lb.; 2 boxes iron-stone, 112lb.; 1 box blast-furnace cinders, 60 or 70lb.† At new works, where these cinders cannot be obtained, a similar quantity of limestone is used.

The descent of the charge, or burden, is facilitated by opening the furnace below two or three times a day, throwing out the cold cinders, and admitting, for an hour at a time, a body of fresh air. This operation is repeated till the approach of the iron-stone and cinder, which is

* This same variety in the coal renders it almost impossible, under one description, to give a just idea of the proportions used at various blast-furnaces: to avoid being too diffuse, I shall confine my description connected with a coal of a medium quality, or a mixture of splint and free-coal, a basket of which will weigh from 78lb. to 84lb.

† A preference at first is always given to blast-furnace cinders in place of lime; being already vitrified, they are of much easier fusion, and tend to preserve the surface of the hearth by glazing it over with a black vitrid crust.

always announced by a partial fusion, and the dropping of lava through the iron-bars, introduced to support the incumbent materials while those on the bottom are carried away. The filling above is regularly continued, and when the furnace at the top has acquired a considerable degree of heat, it is then judged time to introduce the blast; the preparations necessary for which are the following:

The dam-stone is laid in its place firmly imbedded in fire-clay; the dam-plate is again imbedded on this with the same cement, and is subject to the same inclination, on the top of this plate is a slight depression, of a curved form, towards that side farthest distant from the blast, for the purpose of concentrating the scoria, and allowing it to flow off in a connected stream, as it tends to surmount the level of the dam. From this notch to the level of the floor a declivity of brick-work is erected, down which the scoria of the furnace flows in large quantities. The opening betwixt the dam and side-walls of the furnace, called the *fauld*, is then built up with sand, the loose bricks are removed, and the furnace bottom is covered with powdered lime or charcoal-dust. The ignited coaks are now allowed to fall down, and are brought forward with iron-bars nearly to a level with the dam. The space between the surface of the coaks and the bottom of the tymp-plate is next rammed hard with strong binding sand; and these coaks, which are exposed on the outside, are covered with coak-dust. These precautions being taken, the tuyere-hole is then opened and lined with a soft mixture of fire-clay and loam: the blast is commonly introduced into the furnace at first with a small discharging-pipe, which is afterwards increased as occasion may require. In two hours after blowing, a considerable quantity of lava will be accumulated; iron bars are then introduced, and perforations, made in the compressed matter at the bottom of the furnace; the lava is admitted to all parts of the hearth,

and soon thoroughly heats and glazes the surfaces of the fire-stone. Shortly after this it rises to a level with the notch in the dam-plate, and by its own accumulation, together with the forcible action of the blast, it flows over. Its colour is at first black; its fracture dense, and very ponderous; the form it assumes in running off is flat and branched, sometimes in long streams, and at other times less extensive. If the preparation has been well conducted, the colour of the cinder will soon change to white; and the metal, which in the state of an oxyde formerly coloured it, will be left in a disengaged state in the furnace. When the metal has risen nearly to a level with the dam, it is then let out by cutting away the hardened loam of the fauld, and conveyed by a channel, made in sand, to its proper destination; the principal channel, or runner, is called the *sow*, the lateral moulds are called the *pigs*.

In six days after the commencement of blowing, the furnace ought to have *wrought herself clear*, and have acquired capacity sufficient to contain from 5000 to 7000 weight of iron. The quality ought also to be richly carbonated, so as to be of value and estimation in the pig-market. At this period, with a quality of coal as formerly mentioned, the charge will have increased to the following proportions:—5 baskets coaks, 400lb.; 6 boxes iron-stone, 336lb.; 1 box limestone, 100lb. (Mushet.)

In 1 Repertory of Arts, old series, is Mr. John Wilkinson's patent for a small furnace for smelting iron, but I have not heard that it was ever adopted.

The articles, Blast, Blow, Furnace and Iron, in Rees's new Encyclopædia, are well drawn up, mostly from the same sources that I have resorted to. As I have made little or no use of those articles, I refer to them here as worth perusing.

The next plate, is the ground plan and outlines of the furnace commonly used in Pennsylvania. The plate it-

self is sufficiently intelligible, but the following remarks may be usefully added.

Ground plan of the furnace 30 feet square.

Height from the ground 38 feet.

Height from where the boshes begin to slant 26 feet.

Width at the level of the platform of the boshes 9 feet.

From the hearth to the bottom of the boshes 5 feet.

From the hearth to the bottom of the tympan 1-4.

Declination of the wall, from the bottom of the boshes upwards 9 inches per foot.

Furnace hole 21 inches at top, 19 inches at bottom, and three eighths deep.

The wall above the point of the arches, is supported by cross bars of thick iron.

The dam 11 inches high, leaving 5 inches open from the top of the dam to the bottom of the tympan.

The hearth is bedded on 15 inches of dry sand.

Opening of the chimney at top 18 inches: too small.

Some of the vacancies left in the walls to let out the steam (flues of 6 inches square) are shewn on the plan; they may be filled up with coarse loose stone.

Water wheel 30 feet.

Length of shaft 33 feet.

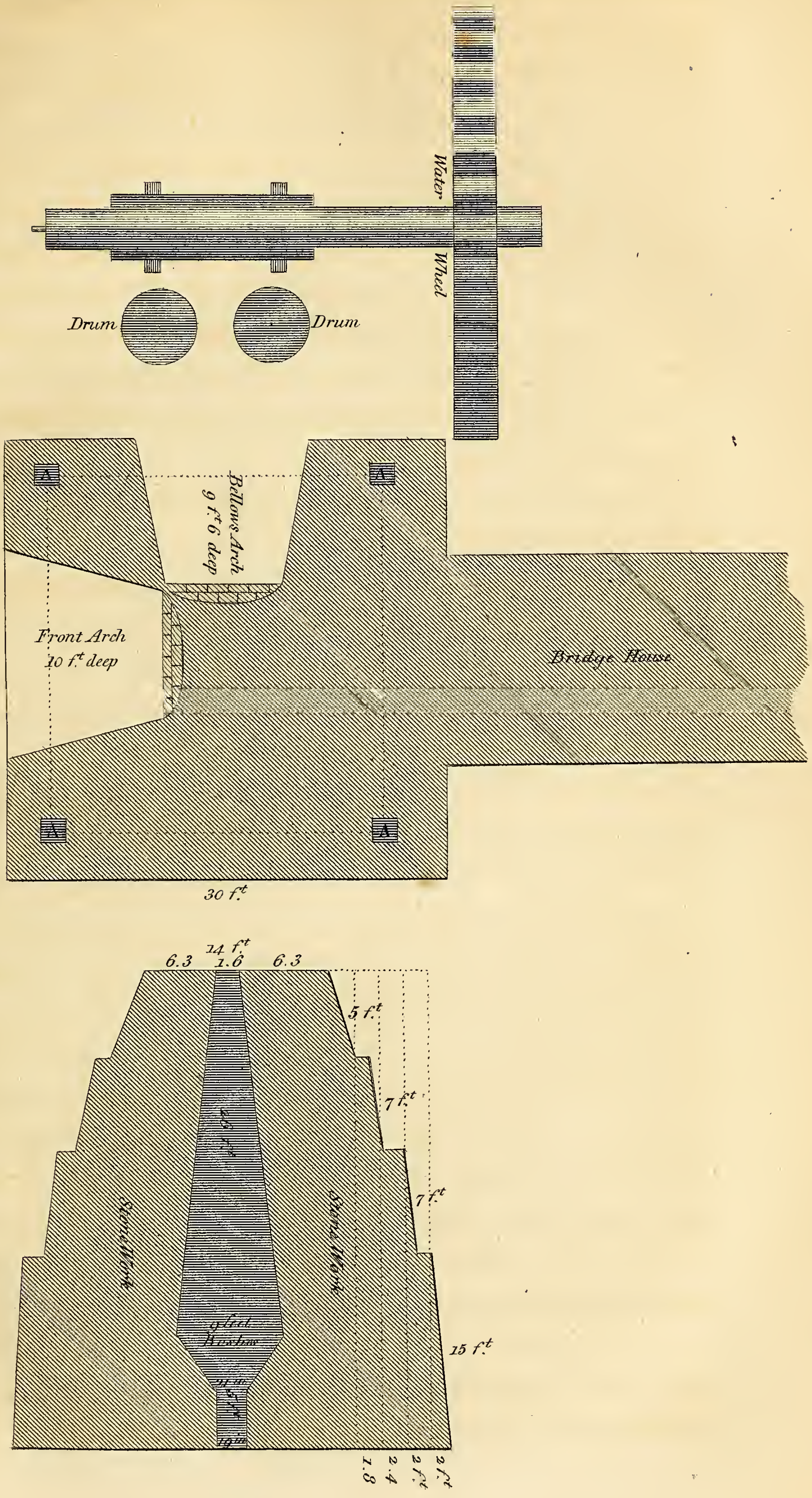
Width of the wheel in the clear 26 inches.

Shrouding 3 1-4 inches by 8 inches.

	Feet.	*In.*
The height from the hearth to the trundle head	31	8
———— from the foundation to the hearth,	5	4
———— from the narrowest part of the boshes to the widest part,	4	3
———— of the tweer (tuyere) from the bottom of the hearth		12
Distance from the nose of the tweer to the opposite wall*	1	6

* The blast of late years is not thrown in quite horizontally, but a little inclining upwards; no doubt an improvement. T. C.

A Modern Pennsylvania Iron Furnace.



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	Feet.	In.
Diameter of the nose of the tweer 3 in. by 2 1-2 in.		
———— drums	6	
Depth of the drums	5	
Strokes in a minute 4 1-2.		
Hearth from the bottom to the boshes	4	8
Dam stone siliceous grit, calculated to last about six months.		
45 cwt. of ore to a ton of metal.		
Charge of ore 320lb.		
coal 15 bushels, each from 14 to 15lb.		
limestone 40lb.		
Charges run every 24 hours: 27 to 28.		
Wages of carters, banksmen, ore diggers, 61 1-2 cents per day.		
———— Fillers 76 cents: ore pounders 69 cents: gutterman 53 1-2 cents: blacksmith 92 cts.		
———— Founder 100 cents per ton for pig metal and 266 1-3 cents per ton for hollow ware.		
Charcoal 200 bushels to a ton of metal.		

In erecting a blast furnace, either sand-stone that will bear the fire, or fire brick should be employed. Sand-stone newly dug out of the ground will be found to contain near ten per cent. of moisture imbibed. If therefore a furnace should require 1000 ton of stone, 100 ton of vapour will require to be dissipated. This can be ascertained by exposing a pound of your stone, to a red heat for two hours, weighing it before and after.

The vents or flues to let out the steam may be repeated every 4 or 5 feet high, and filled with irregular loose stone; they may be 6 inches diameter.

The nose of the tuyere, ought to be kept well plaistered with refractory clay, else the iron is very much disposed to burn.

Of the blast, and the mode of applying it. In al-

most every trial in England, the produce of the furnace has been encreased by encreasing the quantity of air in modern furnaces, beyond the common blast of the furnaces formerly erected. I believe the newly built furnaces of England, have two bellows-arches opposite to each other, and two air pipes. This not only encreases the quantity of air admitted, but in a considerable degree preserves the nose of the tuyere from burning, and the pipe need not project so far into the furnace; nor is it found that the opposite currents of air obstruct each other. This encrease of the volume of air in modern works, *may*, for aught I know, be more advantageous in the pit-coal furnaces, than in the wood-charcoal furnaces; but I am strongly inclined to think that there is great room for improvement in this respect, even among our charcoal furnaces of Pennsylvania. The following remarks of Mr. Roebuck, one of the owners and managers of the Devon iron works, are considered as having been confirmed by all late experience. 6 Ph. Mag. 331.

"This improper measure, however, afforded me the opportunity of immediately putting in practice the plan I have mentioned.

When one of the furnaces was stopped, the other continued to be blown by a blow-pipe of two and three fourth inches diameter, and the produce of the furnace, for several weeks thereafter, was not 20 tons of iron *per* week at an average. The engine at this time was making about 16 strokes a minute, with a stroke of the air-pump, about 4 feet 8 inches long; but when I altered the diameter of the blow-pipe, first to 3, and immediately after to three and one-fourth inches diameter, and regulated the working gears of the engine, so as to make a stroke of five feet two inches long, and about 19 strokes in a minute, on an average, the produce was immediately increased. It continued to be, on an average of nine months

immediately after this improvement, at the rate of 33 tons of iron *per* week, of as good quality as formerly; for during this period, from the 21st of November, 1795, to July 30, 1796, this one furnace yielded 1188 tons of iron. No more coals were consumed in working the blast-engine, or other expences about the blowing machine incurred, and therefore no more power was employed to produce this great effect. It is also of much importance to remark, that the consumption of materials, from which this large produce was obtained, was by no means so great as formerly. The furnace required very considerably *less fuel, less iron-stone, and less limestone,* than were employed to produce the same quantity of iron by the former method of blowing; and according to the statements made out by the company's orders, as great a change was effected in the economical part of the business.

From the success of this experiment, so well authenticated, and continued for several months, I am led to be of opinion, that all blast furnaces, by a proper adjustment of such machinery as they are provided with, might greatly and advantageously increase their produce, by assuming this as a principle, *viz.* "*That with the given power it is rather by a great quantity of air thrown into the furnace, with a moderate velocity, than by a less quantity thrown in with a greater velocity, that the greatest benefit is derived, in the smelting of iron-stones, in order to produce pig-iron.*" However, it is by experiment alone, perhaps, that we can be enabled to find out the exact relations of power, velocity, and quantity of air requisite to produce a *maximum* of effect."

Formerly in England as in this country, when charcoal was used, many of the furnaces were mere bloomeries, worked by hand-bellows, or a small water-power. Then were introduced wooden drums, strongly hooped, with safety valves or snorts, still very common in America, and

worked by a water wheel. To these succeeded as a great improvement in England, cast iron cylinders, in which a piston is worked by the power of a steam engine, (for in that country, iron works are very commonly put into operation by the power of steam) of late (that is within these 15 years) the mode generally pursued of equalizing the blast, is, by means of a column of water. Large iron chests are inverted in water, and the water between the outside containing-vessel, and the inside inverted-vessel, into which the air is thrown, serves to give by the re-action of its weight an equal pressure to the air thus thrown in, and which is again conveyed from the inverted chest into the tuyere. On this subject, I give the following essay from 6 Phil. Mag. 60, 113.

" When it is considered that in the smelting operation the reduction of immense quantities of materials is effected by a compressed current of air impelled by the whole power of a blowing machine, the consequences of the change of air, either in quantity or quality, must be very obvious: when, farther, we contemplate the metal called into existence by means of combustion thus excited; when we consider iron as having the most powerful affininity for the base of that part of the air which maintains combustion; and when we view the debased state to which the metal is reduced by coming into improper contact with it, we must conclude, that the application of blast in the manufacturing of iron, calls for the most minute and thorough investigation. In order to take a comprehensive view of this subject, the following division will be requisite :—

1st, The intimate connection which the quantity of blast bears to the area of the internal cavity of the furnace, and to the nature of the pit-coal.

2d, The various modes by which air is procured, and how these respectively affect the quality of the air.

3d, The various changes to which air is subjected by a change of temperature in the atmosphere, with the consequent effects.

4th, How far increased or diminished velocity and compression alter the results of the furnace.

5th, The form and diameter of the discharging-pipe.

1st, Then, in the construction of a blast-furnace and blowing-machine, the quantity of air to be used ought to depend upon the internal dimensions of the former; which, again, ought to be formed according to the quality of the pit-coal. Upon the softness or hardness of the coal, ought more immediately to depend the height of the blast-furnace. This necessary precaution has given rise to a vast variety of furnaces, of different capacities, from 30 to 50 feet in height, and from 9 to 16 feet diameter at the boshes. Furnaces from 30 to 36 feet are used for the softer qualities of coal, such as a mixture of free-coal and splint. Furnaces from 36 to 45 are appropriated to the burning of splint-coal coaks; and in Wales, such is the superior strength and quality of the pit-coal, that the furnaces admit of being reared to the height of 50 feet.

These various qualities of coal, it has been formerly shewn, have appropriate weights of iron-stone, and, to use the language of the manufactory, are capable "of supporting a greater or lesser burden of mine." The former qualities admit not of having the air discharged in great quantity, unless it is impelled under an uncommon degree of compression and consequent velocity incompatible with the operations of a steam-engine. The reason is obvious: when air, loosely compressed, or comparatively so, is thrown into a body of ignited fuel, the mechanical structure and continuity of whose particles are soft, the air is much more easily decomposed; the ignition, of course, is more rapid: the descent of the materials is promoted beyond their proper ratio, and long before the carbona-

ceous matter has penetrated the ore, or united to the metal, to constitute fusibility. I shall adduce an example, as being most illustrative of this doctrine.

Suppose a blast-furnace, 35 feet high, 11 feet wide at the boshes, properly burdened, and producing No. 1, pig-iron. Let the discharge of air be supposed equal to a pressure two and a half pounds upon the square inch, or equivalent to 1-6th of the atmosphere, or 5 inches of mercury: under these circumstances let it farther be supposed, that 1500 cubical feet of air are discharged in one minute; and that the diameter of the discharging-pipe is 2·625, the area of which is equal to 6·890625 circular inches. Let the discharging-pipe be increased to 3 inches diameter, and let the same quantity of air be passed into the furnace; it is evident that as the area of the discharging-pipe is increased to 9 circular inches, or nearly 1-3d more than formerly, the compression of air must be proportionally diminished. This alteration is soon perceived by its effects; the quantity of scoria increases from the furnace, whilst the consumption of the materials above is also considerably augmented. In a few hours the scoria will have undergone a complete change, from pure white, enamelled with various blue shades, to a green, brown, or black colour, considerably charged with the oxyd of iron*. The same effects will continue, in greater or lesser degree, till all the materials are reduced which were existing in the furnace at the period of diminished compression. The philosophy of this fact may be accounted for in the following manner:—

While the just association of proportions remained, the air was discharged under such a degree of compression as to excite proper combustion: the decomposition of the air by means of the ignited fuel, was not effected in imme-

* The metal will have lost nearly all its carbon, and have become inferior in value 25 to 30 *per cent.*

diate contact with the separating metal, but had, by its uncommon degree of density, resisted decomposition in the ignited passage, and had been decomposed upon the coaks at a greater elevation in the furnace. As a proof of this, we frequently see a tube formed throughout the breadth of the furnace, quite black and apparently cold, formed of the fused materials: when this is removed, a considerable descent momently takes place of coaks heated visibly beyond the common pitch: these inflame rapidly, but are soon again cooled to blackness by the incessant discharge of air upon them. The descending mixture of iron and lava are in like manner cooled around the line of blast; the tube is again formed, and, if not removed, will remain for days together, while the furnace will be otherways working in the best manner.

When by accident or design the compression and velocity of the blast are diminished, the tube begins to burn, and throws off a great many red fiery-coloured sparks, the sides and roof fail, and are carried before the blast in all directions. Sometimes considerable cloats of imperfect iron are recoiled with such violence as to escape the vortex of blast, and issue from the tuyere-hole with such velocity as to inflame in the air, and fall down in the state of oxyd. In the end the tuyere will appear to flame and all the passage inwards shews an astonishing degree of whiteness. The decomposition of the air is instantaneously effected upon its entering the ignited passage; the iron by this means is exposed to the oxygen that is disengaged; and the vast quantity of caloric set free, in consequence of its union with the iron and carbon, produces the astonishing heat now visible, but which formerly took place at a more proper height in the furnace.

From this it will appear, that although a greater apparent degree of heat is visibly produced by the sudden decomposition of the air, and a more rapid descent of materials

for some time is the consequence, yet, as the quality of the iron is impaired, and as in the end the furnace will return to its old consumption of materials as to quantity, the effects of a loose soft blast are conclusively pernicious.

It sometimes happens, that when a loose blast is surcharged with a considerable portion of moisture, or comes in contact with coaks which had been wet when introduced into the furnace, the inflammation which takes place at the tuyere is prodigious: fine fire-clay will be melted down and blown to slag in a few minutes; the sides of the furnace, composed of very infusible fire-stone, is next attacked, and in a few hours will be so completely destroyed as to stop the working, and require immediate repair. Effects similar to those now described will be felt when blast is improperly proportioned to coal of a stronger continuity of fracture and superior quality. Besides the effects produced by the sudden decomposition of iron, others of like nature are produced where a soft coal is used, a small furnace and a great discharge of blast.

It has been found that crude iron, to be properly matured, ought to remain in the blast furnace, according to circumsances, 48 to 60 hours; that is, from the period that the iron-stone is introduced till such time as the metal begins to occupy its place in the hearth in a state of perfect separation. When the contrary is the case, the mixtures arrive at the hottest parts of the furnace before the metal has taken up a sufficient quantity of carbon from the fuel; the action of the blast, and the immediate heat by which the ore is surrounded, forces the iron from its connections to the bottom of the furnace. The quality is de-carbonated, and reduced in its value: to restore this again, the local portion of fuel is increased; this adds to the expence of manufacturing, and diminishes, in some measure, the smelting of the furnace.

When splint-coal coaks are used in the blast-furnace, the blast admits of being thrown in under the highest possible pitch of compression; the uncommon density of the charcoal sustains a very powerful discharge of blast before it is dissipated to facilitate the general descent. Most frequently, large masses of these cinders pass through the whole ignited cavity, and are thrown out below, possessing all the acuteness of their original form and fracture.

This quality of coal is used in all the Curson blast-furnaces, where, to ensure a respectable produce, the air is discharged under a pressure equal to 3 1-4 pounds upon the square inch, or 6 1-2 inches of mercury.

The same quality of coal was used at the Devon iron-works, where, at one time, having all the blast of a 48 inch cylinder engine thrown into one furnace, the column of mercury supported was upwards of 7 inches; the quantity of air discharged under such an impelling power, I found to exceed 2600 cubical feet *per* minute.

The coals used at the Cleugh, Cleland, and Clyde iron-works, are nearly of the same quality at each—a mixture of splint and soft coal. The Muirkirk and Glenbuck iron-works have a coal different from any of the former, and in some particular spots it considerably resembles the English clod-coal.

2d, The various methods of procuring air for the blast-furnace may be reduced to the following:—1st, That procured by cylinders, and discharged into the furnace by means of a floating piston heavily loaded, and working in a large receiver or regulating cylinder: 2d, That wherein pumping cylinders only are used, and the air thrown into chests inverted in water, called the *water-vault:* 3d, That mode wherein the air is discharged from the pumping or forcing cylinder into an air-tight house, called *the air-vault.*

The first method is the original mode of blowing, and is still much used at those iron-works whose erection has

been prior to the last fifteen years. By this mode the quality of the air is less subject to alteration by a change of atmosphere. The principal objection to this manner of blowing, is the want of capacity in the receiving cylinder; which cannot be increased so much as to take away the considerable intervals which occur at different parts of the engine-stroke. This effect is sensibly seen by the speedy and irregular ascent and descent of the column of mercury. In water blowing-machines, where the air is raised by three or four cylinders worked by means of a crank, where the air is received into an air-chest, and forced into the furnace by the continual action of the blast of each successive cylinder, the current of air is steady, and supports the column of mercury with great uniformity.

The use of the water-vault has of late years become very general among new erected works. Its properties are, a steady and very cold blast: the largeness of the receiving cisterns gives them a sufficient capacity to retain every pound of air raised by the furnace, and distribute it to the greatest advantage. This is not the case with the floating pistons, where a certain quantity of spare wind is thrown out at every return of the engine, lest the great piston and weight should be blown out of the cylinder altogether; which, indeed, sometimes happens. The only objection which remains in force against the use of the water-vault, is the tendency which it has to take up a considerable portion of the water in solution, and introducing it into the furnace. A judicious arrangement of the conducting-pipes would in some measure obviate this, as well as the more dangerous tendency which water has to rise in a pipe speedily emptied of its air by the stopping of the engine: a stream of water thus conveyed to the furnace, would be productive of the most awful consequences.

The air afforded by the air-vault is much inferior to that obtained in the former methods. This immense ma-

gazine of compressed air generates a considerable portion of heat, which greedily seizes the damps, which are unavoidable in underground excavations, and conveys them to the furnace. The blast is, however, steady and uniform; and when the inside of the building is completely secured against the passage of air, it is productive of considerable effects in the furnace. In the summer months, however, the air becomes so far debased as to affect the quality of the iron, and change it from grey to white. Every change in the temperature of the atmosphere during this period, is indicated by various changes in the furnace.

The largest air-vault hitherto in use was excavated out of solid rock at the Devon iron works: the fissures of the rock admitted considerable quantities of water; and the same degree of damp would always prevent the possibility of making the side-walls and roof air-tight by means of pitch and paper, &c.

Besides the various natures of blast, as to the strength and equality of the current afforded by different modes of constructing the blowing-machines, a variety in the quality of the air obtained is also an invariable consequence: this is sufficiently known by the effects which it produces in the blast-furnace, and ought to be subject to scrupulous examination.

In this, as in other countries, larger products of cast iron are obtained in the winter months than during the summer and autumn seasons: the quality of the metal is also much more carbonated, and with a less proportion of fuel. In many parts of Sweden, where the summer heats are intense, the manufacturer is obliged to blow out or stop his furnace for two or three months: not only is he unable to make carbonated metal, but is frequently incapable of keeping the furnace in such trim as to make a produce of any quality whatever. In Britain, during the months of June, July, and August, more especially in dry seasons,

the quality of the iron, with the local proportion of fuel, will be depreciated 30 *per cent.* and the quantity reduced to 2-3ds or 3-4ths.

In seeking for a solution of this universally acknowledged fact, our attention is naturally directed to an examination of the various states of air. The quality of the air in winter is more fit for combustion than in summer, is a truth which requires no farther demonstration. Greater coolness, whereby an almost complete refrigeration of moisture takes place, and the presence of perhaps a greater relative proportion of oxygen, may account for this phenomenon. On the contrary, the quality of air during the summer months becomes much contaminated for combustion, by holding in solution a much greater quantity of moisture: the abundance of nitrous particles may also diminish the usual proportion of oxygen.

This will account for the inferior effects of combustion both in common fires and in the blast-furnace; it will also in a great measure tend to solve the curious phenomenon of pig-iron taking up less carbon in summer, although reduced with a superior quantity of fuel. The air discharged most probably contains less oxygen; yet the metal is much less carbonated than at other times, when contrary proportions of these exist. Most probably the deficient carbon is carried off by dissolving in hydrogen, forming a constant stream of hydro-carbonic gas, while the oxygen that is set free unites to the iron; and while it reduces its quality, at the same time the quantity is reduced by a proportion of the metal being lost in the scoria*.

* May not the superabundant azote of the summer atmosphere produce part of these effects, by dissolving a portion of the carbon, and forming carbonated azotic gas, as has been proved by M. Lavoisier? Mushet.

There is no superabundant azot in a summer atmosphere, nor any nitrous particles. T. C.

To correct these occasional imperfections in the quality of the air, and to devise methods to procure air always fit for proper combustion, ought to be an object of much consideration to the manufacturer of cast iron. Whether such a consideration has given rise to the different modes of receiving and discharging the air now in use, I cannot say; I rather think not: a great quantity of air has hitherto been a greater object than a certain and uniform quality; and in a country where there is more temperate and cold weather than hot, it is by far the most important object: to unite both, however, would be an attainment of the greatest utility, and would rank the discoverer amongst the well-deserving of his country. How far the mechanism of our present machinery has been adapted to the exigencies of our atmosphere, will appear upon examining the nature and properties of the air, judged by its effects upon the blast-furnace.

The air produced by the blowing and receiving-cylinder is less changed, and less subject to change, than that produced and lodged in contact with a vast body of air or water. If the blowing-cylinder is fixed in a dry cool spot, the only difference which the air undergoes is an increase of temperature; this is so very considerable, that upon entering the blowing-cylinder immediately after stopping the engine, I have found the thermometer rise fifteen to seventeen and a half degrees higher than the surrounding air. That this heat is generated in the cylinder is unquestionable; but whether it is occasioned by the friction of the piston leather upon the sides of the cylinder, or expressed from the air by its severe compression, I have not yet been able to decide. It very probably arises from both causes, although the latter is sufficient to produce a much greater degree of heat. What effect this increase of temperature has upon combustion we are unable to say, as the degree of heat accumulated will at all times bear a

reference to the temperature of the surrounding air, and as there is no method likely to be devised where heat would not be generated by the action of the particles of air upon each other. When the bulb of a thermometer is held in the middle of the current of blast, as it issues from the discharging-pipe, a temperature is indicated as much lower than the temperature of the surrounding air, as the temperature of the cylinder was higher; and it is most probable that a much lower degree would be obtained, were it not for the previous expression of some heat in the blowing-cylinder. Upon the whole, I think, the quality of the air obtained in this way of blowing uniformly, most fit for combustion, provided the numerous pauses and irregularities of the current of air were done away.

Air forced into the furnace under water pressure always contains a considerable portion of moistrue; the blast of course is colder, as it issues from the discharging-pipe. The temperature differs so much from that of the external air as to sink the thermometer from 54° down to 28° and 30°. Such effects are produced by air coming into contact with water, that, although the temperature of the atmosphere is 60, 65, to 70, yet the blast at the orifice seldom rises above 38: the cold produced in this manner is much increased if the air is surcharged with so much water as to be visible in the state of a fine spray. The leading feature, therefore, of the water-vault, as to its effects upon the quality of the air, seems to indicate an almost uniform degree of temperature in the blast: this can only be occasioned by the warm air in summer taking up a greater portion of the water in solution, the escape of which at a small orifice, and under a great degree of compression, produces the very great depression of the thermometer. I have already hinted at the bad effects produced by moist blasts, and shall, in a proper place, more minutely atttend to them.

The most inferior quality of air used in the blast-furnace is that thrown into the air-vault, and afterwards expressed from thence by its own elasticity and the successive strokes of the engine. The capacity of such a building is from 60 to 70,000 cubical feet; this, when filled, generates a much superior degree of heat to that sensible in the blowing-cylinder. As this heat is produced many feet distant from any mechanical motion, it is most evident that it is extricated from the air, and will readily unite with the moisture which penetrates the building: the quality of the air introduced into the furnace will therefore be in proportion to the quantity of moisture taken up; this will be much more in summer than in winter, as the temperature of the former exceeds that of the latter. The sensation, on entering the air-vault in the coldest months, immediately after stopping the engine, is exactly similar to that experienced upon entering a crowded room in the hottest summer day; the walls are covered with damp, and the superior regions of the vault readily obscure the flame of a candle. The feeling, upon remaining in the air-vault when the engine is at work, is less marked than would be expected where so great a compression of air existed; the sense of hearing, owing to the moisture in the conducting medium, is considerably impaired, and respiration is performed with some difficulty; the light of a candle is faint, and not visible at the distance of a few feet.

I have explained the necessity of just proportions existing betwixt the area of the interior of the blast-furnace, the quantity of air thrown in *per* minute, and the quality of coal. The various modes of blowing, and their respective effects, deduced from strict observation, were also attended to. We have now, 3d, to adduce examples where the various changes of the atmosphere, as to heat and pressure, occasion the most sensible difference in the

quantity of materials consumed, and in the quality and quantity of metal produced.

It has been already demonstrated, that the air in winter, by containing less moisture, is more proper for combustion, and more calculated to produce carbonated crude iron, than the air existing at any other season. From this superior quality the manufacturer obtains advantages, which induce him to wish for a continuance of cool air throughout the whole year. These effects are not, however, uniform; they depend greatly upon a light or heavy atmosphere. The keener and more still the air, the more rapid the combustion. During a severe frost, the descent of the materials is facilitated from one tenth to one fifteenth more than in rainy or hazy weather, and at the same time the quality of the iron is rather improved than impaired. When a change from frost to snow or rain takes place, the effects frequently become almost immediately obvious: the colour of the flame at the furnace head is changed; the tuyere of the furnace inflames, and burns with great violence; the lava, as it flows from the notch of the dam-stone, becomes lengthened and tenacious; the form of it is changed, and the colour undergoes the most visible alterations; the iron no longer retains its complete saturation of carbon, but flows out sensibly impaired of its fluidity, and, when cold, the privation of carbon is most evident by the examination of its fracture.

When such consequences arise from the transition so frequent in winter from frost to thaw, it will be easily conceived that the change effected during the milder and warmer months must produce proportionally additional effects. The increase of temperature by taking up, and holding in solution, a much greater portion of aqueous vapour, will account for the ordinary effects which are annually observable in every work. Where these pernicious

consequences approach to extremity, a solution of the phenomenon will likely be obtained by the examination of the blowing-apparatus. If air is fitted for combustion in proportion as it is free from watery solutions, we are not to expect similar results from these blast-furnaces in summer, which are blown by air from the regulating cylinder, and those blown by air from a water or air-vault. I have for years seen this fact verified, and superior quantity and quality of iron during the hot weather, obtained from a furnace excited by means of blast, from the simple regulating cylinder, with a less proportion of fuel than from furnaces whose air was expressed by means of the water or air-vault. Observations thus made, where every day the effects of the different means could be justly estimated and compared, have led me to the following conclusion: That the quality of the air, as furnished us by nature in our atmosphere, is uniformly more fit for the manufacture of crude iron to profitable account, when discharged simply by means of cylinders and pistons, than when brought into contact with moisture either in the water-vault or air-vault.

So imperfect has the quality of the summer air been found in this country for combustion, where the water-vault was used, that experiments have been made to repair the deficiency of effect by introducing steam into the furnace by means of an aperture above the tuyere. The inducing motive to this act, was a belief, that combustion was diminished in consequence of a diminution of oxygen gas during the summer; that, by introducing water upon a surface of materials ignited to whiteness, decomposition would ensue, a larger quantity of oxygen would then be presented to the fuel, and superior effects, as to combustion, obtained in this manner than hitherto witnessed. The idea was ingenious, and, in its application to the manufacture of cast iron, original; but the

whole train of facts, laid down in this and former papers, as to the effects of a superabundant quantity of oxygen, was overlooked. The event proved in the most complete manner, and on a great scale, the pernicious effects of moisture. The furnace gradually became cooled where the steam entered; the heat, set free by the decomposition of the water and the disengagement of oxygen, increased to an alarming pitch a considerable way up the furnace; the quality of the iron became brittle, and as white in the fracture as silver; the introduction of the steam was still continued, the descending materials were instantly robbed of their heat to facilitate the decomposition of the water, and by-and-by the furnace closed entirely over, and the experiment ceased.

This experiment, performed in a furnace 18 feet high, is a complete proof that heat is disengaged from bodies while they pass from the fluid to the aeriform state. The first instant of the discharge of steam, a very considerable portion of heat would be withdrawn from the fusing materials and united to the water. This, in its turn, would be ignited to whiteness, and decomposed upon the metals and coaks, in a superior region of the furnace. The process continuing for several hours, the materials at the tuyere were at last so completely deprived of the caloric by the continual torrent of steam, that they lost fluidity, cooled rapidly, and at last became black. Had another aperture for steam and for air been opened above these, now entirely shut up by the consolidated materials, the same effects would have been produced; the immense quantity of caloric, disengaged by the decomposition of the ignited water, would now approach nearear to the top of the furnace, another stratum of fusing materials would again become consolidated, till in the end the whole furnace would be set fast from top to bottom. From the introduction of steam into the blast furnace, either as

such, or under a superior degree of expansive force, the following important truths may be learned: That the quantity of oxygen which enters into our atmospheric compound is generally more fit for the manufacture of the superior qualities of crude iron than any mixture which may be furnished by the addition of water: that, although the decomposition of water, by furnishing a superior quantity of oxygen, and by throwing off a relative proportion of caloric, increases the effects of combustion immediately in the vicinity of this chemical analysis; yet, as the water had previously abstracted the heat necessary to its decomposition from the inferior strata, a greater quantity by no means exists in the furnace. The water, in fact, only serves as a medium to convey the heat from one particular spot, but, by attempting to fly off with it, meets decomposition, and renders up not only the abstracted heat, but that which was contained in the oxygen of its decomposition*.

4th, The compression and velocity of the air discharged into the furnace, considerably affect the results of the smelting operations. In the consideration of this subject the various qualities of coals will be found to have an intimate connection with the area of the discharging-pipe and the compression of the blast. It has already been more than once observed, that a soft or mixed quality of coal is more susceptible of combustion than either the splint or clod-coal: the consequence of this is, that, unless the necessary compression of air is used, decomposition is too early accomplished, and the coaks become oxygenated by combustion in a greater ratio than is proper for the carbonation of the metal. To avoid this the column of air ought to be discharged, in the case of soft

* The introduction of vapour or steam is not well understood. I have seen steel made by introducing steam to melted iron; but I do not understand the way in which it operates. T. C.

coals being unavoidably used, under such a degreee of compression, as to resist entire decomposition in the ignited passage. In that case, the iron does not so immediately come into contact with oxygen, as the decomposition is chiefly effected in the superior strata of the separating materials. Under the former circumstance, of a loose unconnected stream of air being thrown upon coaks easily combustible, the quality of the metal, with the same quantity of fuel, becomes oxygenated, the tuyere becomes fiery, and frequently emits sparks of metallic oxyd. The separating iron may be viewed as it oozes from the ore in small gobular masses, frequently on fire, changing its state to that of an oxyd. The combination of oxygen, by altering its density, makes it subject to the re-action of the blast, which at times gives it a direction from the tuyere with considerable violence. Those parts of the iron (by far the greatest) thus oxydated, which escape not at the tuyere, mix along with the fused earths of the ores and limestone, alter their colour, and flow from the furnace more unrevived than at their first introduction. It is, however, very different, even with this inferior quality of coal, where the density of the blast is proportioned to the inflammability of the fuel. Qualities and quantities of crude iron may be produced from this, equal to those from coals reckoned of a superior nature. The metal becomes as highly saturated with carbonic principle as that made from clod or splint coal. The tuyere evinces that decomposition is effected in its proper place. The fluid masses of iron, as they become expressed from the ore, are shivered into spray, before the dense column of air, without exhibiting the least symptom of decomposition. They again unite under the level of the blast, increase in size, and sink through the fluid stratum of earths to the bottom of the furnace. This fact holds out one of the strongest proofs of the great affinity which carbon and

iron mutually possess towards each other. In the case of the iron separating in an oxygenated state destitute of carbon, it immediately falls a prey to its affinity for oxygen. In the latter case, the iron, being completely carbonated, resists decomposition by the sacrifice of a very small portion of its carbon; it further proves, that the affinity of oxygen is greater to carbon than to iron; and that, before iron becomes oxydated, all the carbon is taken up.

The continuity of the particles of splint coals renders the coaks of difficult combustion, capable of withstanding a most powerful discharge of air, in quantity and in the degree of compression, without entailing effects similar to those produced with the use of softer coals: this renders the operations with splint coal less subject to casualty and to change. Carbonated iron with a proper blast is more uniformly obtained, and frequently a very superior quantity. Similar effects are produced with the clod coal, but in a more eminent degree. Discharging-pipes are used four inches in the diameter, and the compression only equal to two pounds on the square inch; yet the same fatal effects are not known as in the use of soft coal, which, with such a column of air, would require the pressure to be equal to 3 1-2 upon the square inch at least.

5th, Upon the form and construction of the discharging-pipe, effects of more considerable importance depend than is either generally allowed or even conceived. At some iron-works, no peculiar shape is adopted: if the tube is sufficient to convey the air, and the mouth of it nearly of the size wanted, the interior construction is entirely overlooked. This indifference, however, is by no means general: variously constructed pipes are used at different works, and at some places it is preferred to throw in the air *from two pipes* whose areas are only equal to one of the usual size.

The various shapes may, in point of the principle of their construction, be reduced to three. (See Plate, Fig. 1, 2, 3.)

To understand properly the objectionable parts of the construction of nose-pipes, it must be recollected, that much has been said to depend upon the blast reaching the opposite extremity of the furnace, as little impaired of the compactness and velocity of its original discharge as possible. When it is otherwise, the results in the internal operations of the furnace must be consequently altered. If the compression is diminished 1-2 or 2-3ds when it reaches the opposite wall, decomposition in that portion must be effected before the air has attained its elevated situation in the furnace. It is even possible to disperse the whole column of air in such a manner that the ignited materials of the opposite side may receive little of its effects to promote combustion.

The discharging-pipe Fig. 1. is frequently used: its length is 12 inches or more; the discharging aperture 3 inches, the other end 5 inches; but this is arbitrary, depending upon the size of the adjoining pipe. From a pipe thus constructed, the air disperses or diverges too suddenly; and at a small distance from the orifice, a considerable portion of it answers but imperfectly the purposes of combustion. Part of it is speedily decomposed and the oxygen brought into immediate contact with the iron. The quantity of metal is reduced by the former, and the quality injured by the latter. Though long custom, by a continued use of such shaped pipes, has prevented their pernicious effects from being observed, yet they must prove, in many cases, detrimental to the œconomical distribution of air, and the manufacture of iron.

Fig. 2. represents a nose-pipe, of another construction, even more exceptionable; because the air dispersing still

more suddenly, in a degree somewhat proportionate to the more sudden contraction of the pipe, a considerable quantity never enters the furnace, but, striking on the exterior wall, is thence repelled.

A discharging-pipe constructed as in Fig. 3. would obviate, in a great measure, the imperfections of the two former: the length of the tapered piece is 12 inches, of the straight pipe, 6 inches; extreme diameter as in the others, 5 inches; diameter of straight pipe, 3 inches. From such a pipe it is conceived that the blast will proceed to the greatest possible distance unimpaired in compression and velocity. So far, therefore, as the absolute force of the blast and breadth of the furnace will permit, decomposition will be prevented on the level of the pipe, and the manufacturer freed from the evils which I have above detailed, as attendant upon decomposition in that quarter." (Mushet.)

For drawings of the ground plan, sections and elevations of a water-blast I refer to Mr. Mushet's paper, 6 Phil. Mag. 362, to Roebuck's paper in the same volume p. 324, copied into Rees's Encyclop. articles Blast and Blow.

Let it then be remembered, that among the points suggested thus far as to the smelting of iron, are the following.

1st, That as the principal object is to procure metallic iron out of the ore, the first step is to get rid of all stony heterogeneous matters, by sorting the ore when necessary, by roasting, by washing.

2dly, That the pieces of ore prepared for the furnace, should not much vary, or much exceed the size of an egg.

3dly, That roasting, in contact with charcoal dust, has the following effects: it drives off sulphureous and arsenical particles, if there be any: it drives off superfluous moisture; it drives off carbonic acid gas by causing the oxygen of the ore to unite partially with the charcoal, and

form that gas; the ore thus approaches still nearer to a metallic nature, becomes magnetic, and requires less charcoal in the furnace to make it into metal. But if the charcoal dust be in too small a quantity, or the roasting continued with access of air too long, or if the red hot iron-stone be exposed without coal dust to a current of air, the ore does not lose, but gains in weight by attracting the oxygen of the atmosphere; it becomes more refractory and infusible, and requires more fuel to metallize it: the difference between a piece of iron ore, and a piece of iron, being for the most part, that the first is, and the second is not, combined with oxygen, carbonic acid or sulphur.

Perhaps the roasting is better done in ovens: Jars in 2 Voy. Mineralogiques planches 1 and 9, has given the oven employed for roasting ores of iron in Styria and Carinthia, and the coak oven of England: the only question here, is, would the convenience pay the expence.

4thly, If the washing be not skilfully performed, there is great hazard of washing away the ochry or metalliferous part of the iron-stone as I think I have seen.

5thly, That it is worth while to ascertain whether the iron ore is accompanied by earths or stones of the clay class, or the limestone class, or of the sand-stone or flinty class, in order that limestone as a flux, may not be indiscriminately used in the same proportion to all kind of ores. The less earth of any kind is mixed with the ore, the less limestone is needed.

6thly, Limestone being the flux that brings all other earths into fusion, a mixture of limestone ore with clay ore, or sand-stone or flint ore, promotes their fusion. Hence, limestone is to be added to clay ore and siliceous ore, but it would be useless and superfluous to add it to a limestone ore. In this case, another kind of ore should be brought to and mixed with the limestone ore. In England, the slag of previous fusions is much used.

7thly, That much trouble and expence may be saved by thus mixing ores of different qualities. So too, the rich primary iron ores, that are not enveloped in earth, may be frequently mixed with good effect with the secondary ores, where the distance will allow the expence of carriage. By the primary ores, meaning such as are found in or near the strata called primitive by the mineralogists, such as hematitic iron ore, heavy compact red iron-stone and similar ores, which may be mixed with the common earthy iron-stones to good effect especially in charcoal furnaces. This is done in England where the Lancashire and Cumberland ores are so mixed with the poorer iron-stones in the coak furnaces.

8thly, That the limestone earth to become a flux, should be added in proportion as much at least as the predominant earth of the ore to which it is applied. Thus, if the iron be enveloped when put in the furnace in clay and sand-stone of which the clay is about 2 parts and the sand-stone one, the limestone should be 2 parts also, or equal to the clay: this rule applies, not to the whole weight of the iron stone, but merely to the earths mingled with it.

9thly, The more moisture your ore, and your charcoal contains, the more fuel and air, you must use to get rid of it: and also,

10thly, The more moisture your ore and your charcoal contains, the more fuel is carried off in forming steam, and is wasted in combining with the oxygen that is formed by the decomposition of the water, which contains by weight 85 parts of oxygen in 100.

10thly, If your charcoal be not well burnt, it employs the contiguous charcoal in the furnace to burn it; wherein there is waste.

11thly, The use of the charcoal or coak, (the fuel) is threefold. It is employed to give heat and bring every thing into liquid fusion: and it is employed to supply carbon to decompose the ore, and abstract from it its oxy-

gen, which prevents its becoming a perfect metal: and it is employed in adding a further dose of carbon to the pure iron, which thereby becomes much more fusible. The carbon in crude iron supercarbonated, is in a great degree mechanically mixed with the iron as the surface of highly carburetted kishy iron, shews: in steel, the carbon is chemically united to the iron. Good fresh charcoal may be considered as containing seven eighths of carbon.

12thly, The limestone is in proper proportion, if the slag is thin and does not retain any particles of metallic iron enveloped in it. Otherwise, the heat has not been sufficient; or the limestone is not in proper proportion; or the charge has descended too soon; or the blast has not been sufficient in quantity, strength, and regularity, to consume the coal; or it may also be in too great proportion for the coal, thereby cooling the metal or the slag in its ascent from the tweer; for the blast that is not employed in producing heat with the charcoal, will produce cold: and still worse, it will re-oxygenate the iron.

The skill of the man who manages the furnace is shewn, in his proportioning his flux to his ore, so that there shall be thin fusion with as small a quantity of coal as possible —in using none but well burnt dry coal, that none may be wasted—in using coal enough and no more to give the required heat and carbonization; for which purpose the air thrown in and the coal thrown in, must consume each other. If the air be in too great proportion, the charge will be cooled: if in too small a proportion the charcoal will not be used up. Wherever great lumps of charcoal are seen floating on the slag or enveloped with it, there is want of skill in adjusting the proportions.

13thly, The charcoal to be entirely consumed without waste, should not be thrown into the furnace in large lumps, for there is not time in this case during its descent, for the air and the iron to decompose it.

14thly, As the charcoal requires time to be decomposed, and the iron ore requires time to be metallized and carbonated, the size and slope of the boshes should be regulated by attentive observation of the process in all its course, during the first period of blast: for ore of one kind may be carbonized quicker than ore of another kind, and therefore may be permitted to descend more speedily (in comparison.) This must be the result of close and local attention.

15thly, I am not qualified to give an opinion, but I would suggest, that in Pennsylvania generally, there has been error, rather in giving too little than too much blast. Also, that a slight inclination of the blast upward rather than an horizontal stream, is to be preferred. For, in the latter case, there is (as I think) danger of cooling the slag, or oxygenating the metal. Also, whether the same quantity of air, would not answer a better purpose from two pipes in opposite directions than from one?

16thly, It appears, that pit-coal or coak furnaces, require to be higher, and require also a greater blast to consume and decompose the fuel than charcoal furnaces; and the ore requires a longer time to be metallized than with wood charcoal: I have sometimes thought the Pennsylvania furnaces are somewhat higher than necessary. I have measured the plates in Jars, and find the dimensions of various furnaces as under.

	Ground plan.	*Width at the boshes.*	*Height from the hearth.*
Iron furnace at Eisenhartz	13	8. 3	33
Treyback, in Carinthia	16	4. –	22
John-Georgen-Stadt, in Saxony	29	5. –	21
Sweden	25 6	7. –	25
Laurwig, in Norway	30	8. –	30

The above are French feet, which are to the English as 114 to 107.

Jars has given the steel furnace, and the foundery furnace of England, but not the blast furnace.

17thly, Thus it appears, that a smelting furnace may be considered as divided into three parts; viz. the uppermost portion from the opening at top, downward to the narrow part of the boshes wherein the process of cementing goes on; that is, where the crude ore is gradually deprived of the oxygen, or substance that demetallizes it, by means of the carbon of the coals. Whether this be compleatly effected, depends first on the charge of the furnace; whether the coal, the iron-stone, and the blast, be each in due proportion to each other, so that no part of either shall escape the action of the other: secondly, on the degree of heat given to the charge, for this union of the carbon of the coal, with the oxygen of the iron, does not take place, but in a full red heat: thirdly, upon the size of the particles of ore, coal and limestone: and fourthly, upon the time the charge takes in descending from the top of the chimney to the bottom of the boshes, where the fusion or melting takes place; for, if it descend too quickly, the iron will not be sufficiently carbonated; part of it, in the form of ore, or oxyd, will be turned into glass with the slag, and the iron in the hearth will be imperfect *white* iron without a regular grain. On the contrary, if the proportion of coal be considerable, and the descent of the charge protracted, the iron will be *smooth-faced pig;* carburetted or supersaturated with carbon; it will be extremely fusible, more so than cast steel, which, in many properties, it greatly resembles; and a substance like plumbago or black lead, called kish, will float on its surface. This kind of pig, however, is very valuable, being used for castings of all kinds: where the coal, the heat, and the stone, have been in due proportion, the iron will be saturated with carbon, or nearly, so as to be metallic throughout. This is *forge pig;* a kind of iron uni-

formly preferred for tough and heavy work. Hence, this last or *forge pig*, is *carbonated* iron, wherein the charcoal has nearly abstracted the whole of the oxygen: *smooth faced pig* is *carburetted* iron, where the charcoal has superabundantly combined with the iron: the *white* and the *mottled* iron, is imperfectly and irregularly carbonated, and is least valuable.

The other parts of the furnace, are, from the boshes to the entrance of the blast, in which is to be considered whether the width and slope, will admit of the required regular descent—from the bottom of the boshes to the entrance of the blast where the iron and slag is finally fused; concerning which the points of consideration are the quantity, the velocity, and the direction of the blast—and the hearth, in which the melted metal is deposited.

18thly, In addition to the observations as to the proportions of charge, I would observe that in England, a common charge by weight, is four of coak, three and one-third argillaceous iron ore, and one limestone. At a furnace in England producing good melting iron, of a quality between the highly carburetted dark grey iron, No. 1, and the imperfectly white iron or forge pig carbonated—working an argillaceous iron ore containing 27 per cent. of iron—the furnace being 45 feet high, and twelve and a half feet diameter at the widest part—consuming 2500 cubic feet of air per minute, issuing from a tuyere of two and three fourth inches—the average charges of coak per *shift* (or 12 hours) are fifty of two and three-fourths hundred weight each, or nearly seven tons. The calcined or roasted ore for good melting iron, is of the same quantity, but for forge pig, or the least carbonated variety, 6 of coak to 7 of ore: the unburnt limestone is as 4 to 11 of ore. This furnace with such a daily charge produces 40 tons of metal per week.

A wood charcoal furnace requires somewhat less lime

than a coak furnace: and rich ore requires less than poor ore. The rich Lancashire ore of England worked with wood charcoal does not require more than one-fifteenth, or even one-twentieth of limestone: for as the ore abounds in metal, it contains a less quantity of earths that require to be fluxed.

As to the charges in this country, where charcoal and not coak is used, they vary considerably, but I do not find that the variation sufficiently depends upon principle. I have already stated a common charge.

According to the report of Mess. Dangenoux and Wendell on the iron works of Styria and Carinthia, 1 Jars 58, the coal measure at Eisenhartz, is three feet diameter at the top, one and a half foot at the bottom, and two feet deep.

The ore measure is 26 inches high, 21 inches top diameter, and 12 inches in the bottom. The charge is 2 measures of charcoal to one of ore.

At Vordenburg, the charge is 3 measures of charcoal, each measure being 30 inches deep, by 30 inches top diameter, and 18 inches bottom diameter, to one measure of ore, the measure being 18 inches square and 17 inches deep. All this however, as well as the proportion of flux, is of no consequence to the reader, and gives no information unless he knew the quality of the iron-stone. In many parts of Germany as I find by perusing the numerous accounts given by Jars, they make use of *waacken* as a flux. What Mr. Pott in his Lithogeognosie meant by waacken, I know not; it is impossible not to regret that a work in other respects so excellent should be rendered useless by the want of an accurate mineralogical language. The present waacken of the Germans, is an argillo-siliceous stone, consisting of nearly equal parts of the 2 earths. Hence the ores to which it is used, must be those wherein the particles of iron are enveloped in calcareous or limestone earth.

The toughest iron and that which requires most fuel, is from the siliceous ores; next to that the argillaceous; the most fusible and least tough iron is generally from calcareous iron-stones. All these I apprehend may be qualified by a due mixture with each other.

[*To be concluded in next number.*]

The next number will finish the article *Iron* and also *Steel.* I wish I could have made the preceding papers more popular and less chemical, but I could not. The time is at hand when young iron masters will find it necessary to become acquainted with chemistry; to such, the present essay will furnish abundant matter for reflection. It is not intended for the iron masters of the present day; for men of great industry, great experience, and generally of great wealth honourably acquired. Such men need no instruction, and I am not competent to give it if they did.

The other branches of manufacture, I shall treat in the same way, more or less at length as my materials induce me.

Wilkesbarre, March 16th, 1813.

Dear Sir,

HAVING observed by my last number of the Emporium of Arts and Sciences, that you had undertaken the editorship of that work, I send inclosed a copy of manuscript directions, in my possession, by an English manufacturer, for making bleaching liquor for the use of papermakers. I have preferred giving you an exact copy of it and the draught, to making any alterations in the style or drawing. Your knowledge of the subject will enable you to make the necessary corrections in both.

As the method of bleaching, by means of the oxygenated muriatic acid is, I believe, not known or in use in our paper-mills, it may be useful to the profession here to be informed, of the mode and process of conducting in Europe that part of their business.

I should be very happy to hear from you occasionally, and am,

Dear Sir,

Very respectfully your obedient servant,

Professor Cooper, Carlisle. JASP. CIST

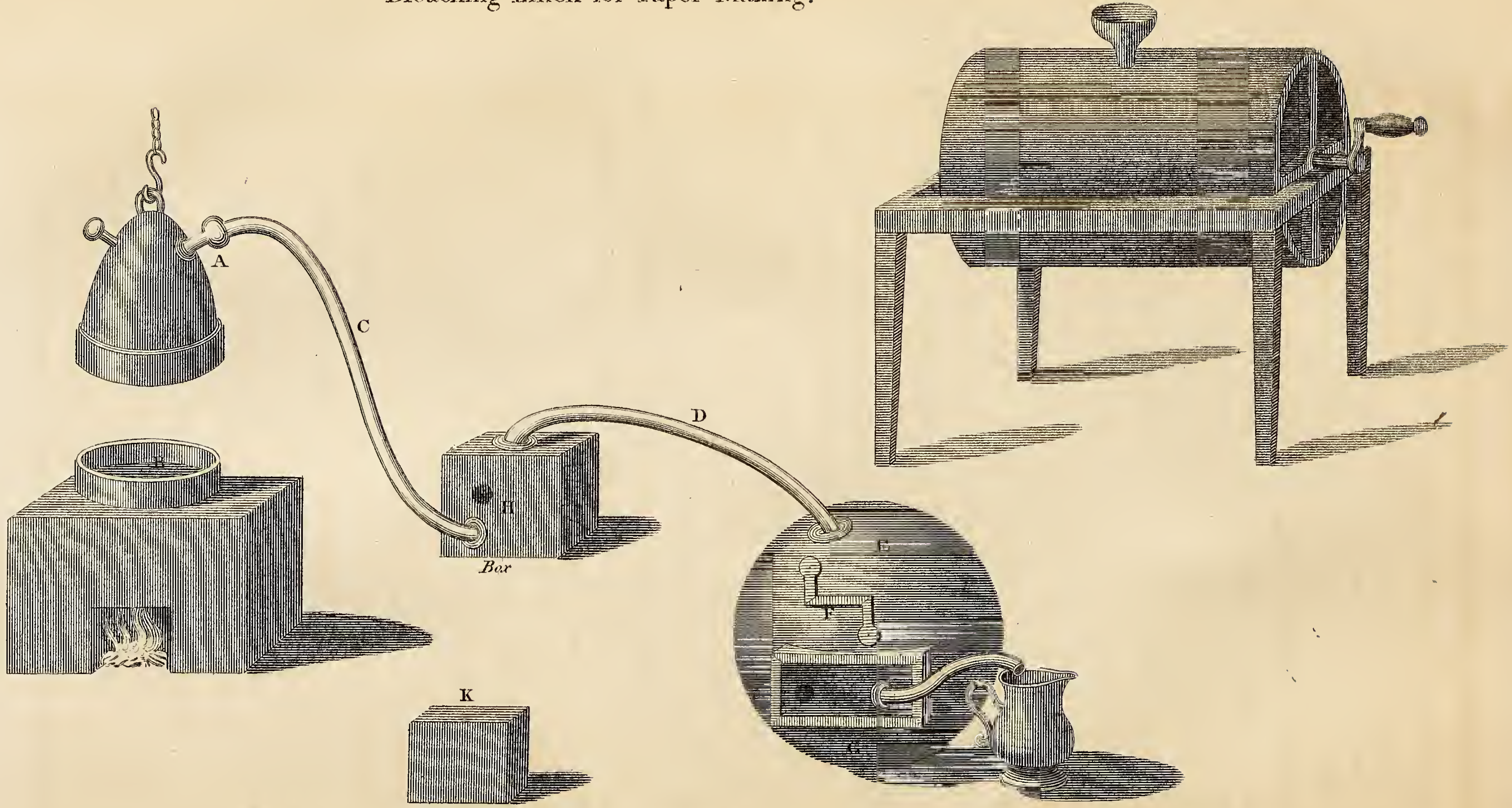
Directions for making 225 gallons of liquor for whitening stuff for papermakers.

First put into the still 21 gallons of salt brine, as strong as can be made, which may be known by putting in salt until some of it remains unmelted, then put into a box 45lbs, of the best salt, likewise 90lbs. of the best ground and powdered manganese, mix them very well until all appears as manganese, then put that mixture into the still, put on the head of the still, first stirring or blending it with a shovel until it is in motion, then have 126lbs. of the best vitriol in 6 jugs ready, put some vitriol into the tundish, first putting in the service pipe and luting it with clay as you see in the plan, then let in the vitriol gradually until you hear the jug on the reservoirs blab, then stop the vitriol, which must be done by a small iron rod made for that purpose to fit it, so let in your vitriol by degrees until all is in, which must not be less time than four hours at least, then 30 minutes after being in, light the fire and keep it very moderate for 10 or 12 hours, then you may keep the fire something stronger for the remainder of the time until the operation is finished, which will be 24 or 25 hours from the first putting in of the vitriol, then stop the ear pipe of the lid and let it stand 14 hours at least before you draw it off for use.

N. B. When the vitriol is all in, take out your tundish and have a ball of clay for luting the place it stood in; first of all, fill your reservoir with clear water to within 7 inches of the top of the consolidating lid—then put into the reservoir 50lbs of the best hot lime, finely sifted—agitate the reservoirs for 15 minutes, then put on your lid and fix your bubbling jug as you see in the plan; let the agitator be kept turning during the whole process, especially when the vitriol is going in; after you draw off your liquor in bottles, what remains in the reservoir of lime and liquor put it in a hogshead and fill it with water, stir it and let it stand until the next work, by putting it in the reservoir that you may have no loss; the same is used in what remains in the still of the old lees, let it be put in a vessel or cistern which stands contiguous to the still, and is also lined with sheet-lead; always used it will be a saving, as it answers better than the first by keeping it up to the 21 gallons with brine as directed; the saving is this, viz. that instead of 90lbs. manganese 74lbs. will be sufficient and 34lbs. salt instead of 45.

N. B. You are to take the greatest care not to let any of the manganese touch the reservoir, as the least particle of it would spoil the whole process.

Bleaching Linen for Paper Making.



W. Strickland del.t

C. Tiebout sc.

If you have a mind to make liquor for bleaching linen cloth, let your liquor in the reservoir be 5 or 6 degrees strong of the hydrometer glass by pearl or potash, and the rest of the process as before; be sure to wash the reservoir very clean from lime, and be careful of your luting for fear of smell; the head of the still and lid of the reservoir is luted with water as you see in the plan. If you make it for linen, have the opinion of some man conversant in bleaching; if the glasses can be got, I will write the use of them. (See the plate.)

A The cap of the still.

B The body of ditto, which, as you see, stands 7 or 8 inches above the surface. The cap is in the form of a hive, entirely hollow, with the tundishes soldered, as you see, one for the use of charging the still with the vitriol, and the other takes off the inflammable air, which is C, then it enters the intermediate box, through which it passes through the pipe D, and enters the vessel by the reservoir, which is E. The pipe stands about 11 or 12 inches above the surface, 1 inch bore, but does not dip in the reservoir; it drops its strength in its reservoir, which the motion of the wheel circulates the body; the wheel or windlass, is the letter F, which is only the handle and a boy continually turning it during the whole process; ×⌐ the wheel is in this form, with the arms the full diameter of the vessel; the intermediate box, as you see: the pipes or tubes stand 12 inches at the top, I mean from the horizontal of the top of the vessel. The centrepipe, which is H, dips in the water which is in the intermediate box and has two nostrils which give air, although being under water; the intermediate box has always 4 inches of water, which is put in every time the still is charged, and has a cock at the bottom to empty it occasionally; there is also the consolidate vessel, which is G, it stands about 7 inches high, but made fast to the top of the reservoir. The consolidate vessel is as thus: it has a lid, and on the lid is made fast a pipe which dips in the water 1 inch; the lid is taken off to put the lime-water in: also there is another pipe which stands about 3 inches on the top, and in that pipe fits a tube which dips in the pitcher as you see in the draught; the lid of the consolidating vessel fits in a cavity the same as the cap of the still, and the cavity is filled with water to keep it staunch; also there is a cock at the bottom of the reservoir to rack off the liquor, and another at the bottom to cleanse it out. The letter K is the vessel which the old lees are thrown into as before mentioned. As to the proportions of

the vessels I shall be very exact—the depth of the still is 2 feet 5 inches; the diameter 2 feet 3 inches; the cavity where the lid fits is 13 inches deep; the proportions of the intermediate vessel are 16 inches long, 12 inches broad, and 11 high; the reservoir is in depth 20 inches, diameter 4 feet 8 inches; the consolidating vessel which dips in the water is 14 inches square, 7 inches high at the top, and the lid has two handles to take it off. When you are going to put in the lime water, the cap of the still is elevated by a pully, which at the top of D° you see a hook made fast to D° for the same purpose, to put it on and take it off without any farther trouble. The still is laid in a metal boiler, and underneath the still is 4 inches of sand, but the body is a cavity all round to the top which is inclosed with brick work; the whole apparatus is lead. N. B. The reservoir is also lined with lead, as also the cistern which the old lees is thrown into. The reservoir is a wooden vessel, and, as I said before, lined with sheet lead. J. K.

REMARKS.

I am obliged to Mr. Cist for this communication, which bears the marks, tho' rough, of practical experience. But the proportions of the materials are not accurately adjusted. Twenty one gallons of saturated salt brine will not contain quite 60lbs. of salt, for 16 ounces or a pint of water, will not quite dissolve 6 ounces of salt. Hence the proportions here, are salt 105lb. manganese 90lb. oil of vitriol 126lb. water 160lb. But the best proportions are, by weight, salt 8 parts, manganese 3 parts, oil of vitriol of commerce (weighing 29 1-2 ounces to the wine pint) 6 parts, water 12 parts. So that to 112lb. of salt, there should have been about 50lb. manganese, and 80lb. oil of vitriol. These are the common proportions of the bleachers in Manchester. The receipt of Mr. Cist's correspondent is therefore wasteful in the dearest of the articles. If there should be a little less oil of vitriol, nothing is wasted but the salt, which, in this country, is of little consequence comparatively.

There have been two or three patents for bleaching paper in England. I know not how they succeeded. I shall have occasion to detail what I know on the subject of bleaching generally in a future paper. But as the present communication is entitled to an insertion, and the subject is before me, I shall give, for the present, the following process, which I am firmly persuaded is of much more importance than any thing that has hitherto been published on the subject. It has been already published in Dr.

Mease's edition of the Encyclopœdia, a very useful work, but containing much that may be thrown out, and wanting much that might be usefully added. I wish the Doctor would re-edit that book.

In the year 1790, a Frenchman came to Manchester to propose a new discovery in bleaching. A meeting was called, but the information he thought fit to give, was not of consequence enough to entitle him to attention. Mr. Thomas Henry, (the father of Dr. W. Henry, the chemist) myself, and Mr. C. Taylor, (afterwards secretary to the Adelphi Society of Arts) agreed that this was meant to be Berthollet's application of Scheele's discovery of the dephlogisticated marine acid (oxymuriatic acid.) We set to work, and made a quantity of the acid, and bleached with it several specimens of calico; imperfectly, because they required the cleansing of alkaline lixivia. During our experiments, it occurred to me, that as manganese was dirty, frequently impure, and frequently given out carbonic acid when treated with oil of vitriol, and that the residuum was not convertible to any known use, we had better employ minium or red lead, which I knew to contain 12 or 14 per cent of pure air.

It succeeded perfectly; and the vitriolated lead which formed the residuum, might be reduced to lead again. In hastily and carefully combining the vapour of this very pungent and unpleasant acid, by a strong bottle, well corked, it occurred to a friend of mine, Mr. Baker, a manufacturer of oil of vitriol, that the acid in question might be at once made without distillation in a vessel sufficiently strong. He tried it at home in a strong decanter, and succeeded. I embarked with him in reducing this discovery to practice, and until I came to this country, used it with perfect success on from 800 to 1200 pieces of calico weekly. The process was never published in England; I gave it to Dr. Mease, and nobody has noticed it. I give it again, that it may be more extensively known.

The plate accompanying the paper communicated by Mr. Cist, contains also a view of one of the machines used by Mr. Baker and myself, to make the oxymuriatic acid in.

The method of making this acid for bleaching, commonly used in Manchester and elsewhere, is by adding to 3 parts, by weight of manganese, 8 parts of common salt and 6 parts of oil of vitriol, and 12 of water....These are distilled together, and the products received in barrels of water, arranged in the manner of WOLFE's appara-

tus by tubes communicating from the retort to the first barrel, and from the first to a second. Sometimes the water is only impregnated with the acid, sometimes it is made to saturate lime or pearl ash. This process cannot be used with economy: the trouble and expence of retorts, and the attendance on the fire renders it far too complicated. It has not yet, and never will answer for goods in general. Where particular patterns are suddenly wanted for the market it may pay.

The writer of this article attended for three years continually to the bleaching of cotton goods of various kinds, to the amount of 800 pieces of callico per week, on the average of the year, by the following process. The goods underwent three boukings, as described before in this article, and two acid baths. The third was the oxygenated muriatic acid made as follows. In a building of one room on a bank and another over it, were placed on substantial frames or tressels, five wooden cylindrical machines four feet diameter by five feet long, the staves two and an half inches thick and well dovetailed. Into each of these, twice a day, through a funnel inserted in a two inch augur hole and let through the floor of the upper room was poured 75lb. of salt and 25lb. of red lead. To this was added 40lb. of oil of vitriol, weighing twenty-nine and a half ounces to the wine pint.

The machine was then filled with water, the augur hole stopt with a plug and rag, and then turned round 20 or 30 times, and in 15 minutes the acid was made.....The vitriolic acid acts on the salt, and the marine acid thus produced acts on the red lead, which in a few minutes is deprived of its oxygen, and converted into vitriol of lead. The handle of each machine was fixed on the centre of one of the ends with two cross-bars.....The acid when made was let off on the pieces placed in covered wooden vessels in a room adjoining and below. It frequently occasioned a spitting of blood among the workmen who took out the pieces, but was never attended with any further deleterious effects; laudanum relieved the short phthisicky cough. One of these vessels full was allowed to 60 muslinets. No lead remained in the liquor, for vitriol of lead is insoluble.

This process may be imitated in a small way, by pouring into a *strong* vial with a glass stopper, about an ounce of spirits of salt on a tea-spoonful of red-lead; stop the vial, heat is generated, the lead turns white and a very strong oxygenated acid is produced in a minute's time. But this acid will contain a little lead, while the acid made with vitriol and salt contains scarcely any. This acid has

lately been recommended by *Guyton Morveau*, as an effectual destroyer of putrid exhalation.]

It is obvious, that after the pulp of coloured rags is well cleansed from impurities, and washed well, and the water let off, this liquor can be conveyed upon it, in a covered wooden cistern. The pulp must be stirred once or twice by means of a long wooden rake, and a hole made for the purpose in the cover. It should thus remain 12 hours; and then be well washed to carry off all the acid.

The effect of this acid may be tried thus: into a *strong* six ounce vial, put a tea-spoonful of red lead, and 2 tea-spoonfulls of spirits of salt, mixed with as much water—put a piece of printed calico inside the vial, and close it in, by means of the cork—shake the vial to make the ingredients mix, and in a quarter of an hour the colours will be discharged by the vapour, or nearly so. T. C.

FOREIGN COMMERCE.

THE following essay in substance and nearly in form was first pulished in the Northumberland and Sunbury Gazette, in June, 1799; a second edition in 1800. The facts therefore are confined to that period. I republish it now, in conformity to my promise at the beginning of this number, because I am persuaded that all the leading principles of this paper are sound; and because it is high time to bring the COMMERCIAL SYSTEM into full discussion. If we are to adopt it, let us understand it first.

The measures necessary for defence, have also altered my opinion as to the propriety of introducing home-manufacture, and establishing a navy. If any reliance could be placed on the political integrity of Great Britain, I would not put pen to paper toward the introduction of Manufactures. We should be prosperous and happy enough as an agricultural country; but I fear no such reliance is to be placed on any government swayed by the principles of mercantile policy, whether there or here. In this opinion, I am not singular.

I consider it as against the interest of a country, to give particular encouragement to any employment of capital whatever; not even to agricultural investments. The calculating foresight of individuals, actuated and guided by the light of interest, will dis-

cover much more surely than any government can, how and where capital and labour can be employed to the most profit: and as I regard the aggregate of the wealth of the citizens, to be synonymous, with the wealth of the nation, it can seldom be wise for the administrators of national concerns to interfere in this respect, either by encouragement or prohibition. For many still stronger reasons, Commerce, ever clamorous for protection, is never worth protecting. In proportion as any employment of capital calls for national assistance and protection, it deserves none. The very demand itself, amounts to demonstrative evidence that the investment is injudicious, and ought to be abandoned. But of all employments of capital, that which calls for navies to guard it, and hourly jeopardizes the peace of the nation, deserves the least.

We are now unfortunately reduced to such a situation, that a navy for the defence of our coast, and a standing army for the defence of our frontier, seem permanently necessary: for it will be madness, after the experience of the revolutionary war and the present war, to trust to raw undisciplined militia, suddenly called from the plowshare to the bayonet.

For this state of things, we are indebted to the COMMERCIAL SYSTEM; of which every hour and every event that passes, evinces to me the danger and the cost. What is the origin of the present war in which we are involved? First, Great Britain, in April 1806, by the paper blockade of the Ems and the Weser; and again in May 1806, by a similar blockade from the Elbe to Brest; then France, in retaliation, by the Berlin decree of November 1806; then Great Britain by her orders in council of March and November 1807; then France by the Milan decree of December 1807; then Great Britain by her blockade of Carthagena; and then France by her decree of Bayonne, depredated on our commerce, under principles of blockade, perfectly new to the law of nations. Not satisfied with these acts of injustice, the two belligerents played into each others hands, by means of the *license trade*, to annihilate the commerce of America, and allowed to each other, being mutually at war, that very commerce they refused to us, with whom they were at peace. Doubtless neither on the one side or the other of the powers at war, can this conduct be defended: but our course certainly was, to let our merchants know, that if it was worth their while to engage in a traffic liable to so many interruptions, they might; if not, they might let it alone; and the people at home must be content to dispense with luxuries, intro-

duced under so many difficulties and and dangers. Most assuredly such a trade was not worth protecting at the *expence of a war.*

Meantime, our merchants encouraged without scruple the employment of British seamen on board their ships, and carried on their commerce to a very great extent by means of British subjects. The trade of false protections, and the disgraceful practices accompanying it, was undisguised and notorious, in our seaports; and formed a worthy counterpart to the forgeries of American documents openly sold at London. Great Britain, under pretence of searching for her own subjects, impressed American seamen also, whenever it suited the interest or inclination of the naval commanders. Thus it was: *Iliacos intra muros, peccatur et extra.* This is manifestly a mercantile war in all hands. Every cause and reason assigned, every paper and manifesto published, is of a commercial complexion; and all the difficulties that at this moment stand in the way of settling it, arise as much from the conduct of our merchants at home, as of the British abroad. It is the mercantile interest and the commercial system, in both countries, that have tempted and driven their respective governments into this war.

The British in, my opinion, had a right to prohibit the non-accustomed trade: they had a right to complain that our merchants navigated with their seamen, whom they wanted for national defence. We also have great right to complain, that the British commanders impressed our seamen as well as their own; adding to a careless, disregard of justice, the irritating insolence of office. But it is an obvious reply on their side, that to the unavoidable difficulty of distinguishing between the two nations, our own conduct has superadded new ones, that might and ought to have been avoided. Before we claimed justice we should have done it; and prohibited our merchants from the employment of British seamen, 'ere we went to war in claim of our own. I see many obstacles to the adjustment of this unpleasant system in the first instance, and still more as to its permanence.

I say nothing of the right of *expatriation.* I hope the question will not be burthened with this discussion. Certainly it is not the law in any country of Europe that I know of. In this country, the question came under review in *Talbot v. Jansen*, *Murray v. the Charming Betsy*, and *M'Ilvaine v. Cox;* but it has received no decision except that of Chief Justice Elsworth, in the case of Capt. Isaac Williams, which completely negatives the right. I think this right may be well defended on general principles; nor need

any good government be afraid to admit it, subject to some reasonable modifications in the exercise. Nor ought the slavish doctrines of Story's case and Calvin's case, to settle the law of the present day. But as the law now stands with *us*, how can *we* obtrude the question?

For all these difficulties, we may thank the commercial system. This war may continue a dozen years for aught we know; and it is more than probable that our seaports will be bombarded. Is the commercial system worth this? will it remunerate us? It is now clear, that a navy, and a standing army, will both become permanently necessary; and I shall not be sorry to see the one and the other extended far enough for home defence, and no further. But the navy will not stop here; the mercantile interest, will urge with incessant perseverance, its increase, for defence, not of our sea coast at home, but of their vessels abroad: and then keep clear of wars if you can. At what expence their ships are defended they care not. They look to their own interest, and leave other people to do the same: and who can blame them?

The following is the first of a series of papers that I will occasionally dedicate to this most interesting subject, in which I shall insert such views of the question, as have occurred to me, since the following Essay was written. T. C.

Commercial Licences granted by the English Government.

In 1802	68	In 1807	2606
1803	836	1808	4910
1804	1,141	1809	15,226
1805	791	1810	18,356
1806	1,620	1811	7,602

POLITICAL ARITHMETIC.

The comparative value of the *Agricultural* and *Commercial* systems, begins now to be somewhat understood in Europe, among those who have turned their attention to political economy. But I suspect it is a new subject here. It is a very important one every where; and I sincerely hope, we shall endeavour to profit in this

country, by European experience. It is impossible to enter fully into the discussion within the bounds of a newspaper Essay; nor can the back country supply the necessary materials for it; but imperfect as this will be, I am fully satisfied that there is a class of readers, whose approbation I shall be proud of, who will peruse it with attention, and regard it with indulgence.

It seems determined in *America*, that we shall be a commercial country. Our navy, our army our loans, our increased taxes have arisen from our Commerce. This is cried up as the grand source of national wealth, and power, and prosperity. I, on the contrary, am firmly persuaded that until the home territory of a country be well cultivated and peopled—until manufactures founded on population, are in a state to require other markets to be sought, foreign commerce is a losing concern; an appropriation of capital, seldom expedient, frequently detrimental; that it has proved so, wherever agriculture has been thrown into the back ground to advance the commercial system; that to afford it support by prohibitions and bounties, or protection by engaging in wars on account of it, or manning navies for its defence, is equally unwise and unjust; that if it cannot be carried on without the fostering aid of government, it ought like every other losing scheme to be left to its own fate, without taxing the rest of the community and their posterity for its support. That foreign commerce is unnecessary as an investment of surplus wealth in this country, where there is so much land calling aloud for cultivation and capital, and so deplorably managed for want of these; that all the usual motives to foreign commerce, greatly fail in this country, which comprizing every climate, may be made to supply every variety of produce from its own industry.

1st. *Of the meaning of Commerce.* The barter or exchange of commodities between different persons is *Commerce.* If it be confined to the citizens of any country among themselves, it is called *internal commerce*, or the home trade; if between the citizens of one country and those of another, it is *external commerce*, or foreign trade; if by means of the citizens of one country bartering abroad the produce or manufactures not of their own, but of other countries, it is the *carrying trade.*

2dly. *Capital employed in the* HOME TRADE, *is more beneficial to the country than capital employed in the* FOREIGN TRADE, *or the carrying trade.* Suppose a merchant of New Orleans purchases $ 1000 worth of pork and whiskey from a Kentucky farmer,

and sells it to a Louisiana sugar planter for 1200 dollars worth of sugar, and exchanges that sugar for 1400 dollars worth of cotton and woollen manufactured at Rhode Island—here is a spur given, a stimulus to the industry of our own citizens in Kentucky, in Louisiana, and in Rhode Island, to the amount not of the merchant's gain upon his thousand dollars merely, but to the whole amount of the thousand dollars, all of which circulates, becomes invested and productive again at home; and three at least of our citizens are gainers by each other in the first instance. This is internal commerce or the home trade.

If a merchant of New Orleans, sends 1000 dollars worth of pork and whiskey to the Havanna and brings home $1000 worth of cigars, his capital is employed as much for the encouragement of Spanish as of American industry; such a man is just as valuable to the Spanish colonies as the American states, excepting so far as he expends his gains in the latter country. In the case now put, he is usefully, but not so usefully employed to this country, as in the former.

Suppose an American merchant employed in carrying produce of one of the French colonies to Great Britain, for which he receives in return cotton goods of Manchester. Such a merchant may reside in Philadelphia, and spend part of his gains there, but he is the agent of France and Great Britain; the capital employed to load his vessel stimulates the industry of the French planter and the English weaver; and it is accidental only, if the vessel itself that earns the freight, be American. The wages paid to the sailors, are expended abroad, and add to the wealth of other countries. This may be gainful to the merchant in times when freight is high, but the gain to the country he lives in, consists only in that part of his income that he spends there: and even that comes out of the pockets of home consumers. For if Mr. America purchases the coffee of Mons. St. Domingo, and then invests it in the sherry of Signor Spain, it is clear that he gives encouragement to St. Domingo and Spain: and if the wine of Spain be brought to America, he gains ultimately at the expense of the Americans alone. These objections do not apply to a coasting trade, where the carriers are employed by the home producers.

Hence, in the home trade, or internal commerce, the capital and the profit are both gain to the nation; they are both expended in stimulating and rewarding home industry; in promoting permanent and productive improvements at home.

In the foreign trade of exchange, the capital employed, is equally beneficial to the country where the merchant lives, and the

country to which he trades. His own country reaps the advantage of whatever he expends there of the income he acquires.

In the carrying trade, the merchant belongs to foreign countries; his own country is no further benefitted by his industry, than the expenditure he makes in it, of part of those gains, which the home consumer enables him to acquire.

3dly, *The capital employed in the home trade, circulates twice or thrice, while a capital employed in the foreign trade circulates but once.* Reflect upon the travels, if I may so call them, of a capital employed *at home.* 1st, It goes from the home merchant to the home producer; the farmer or manufacturer. 2dly, It is paid over with profit to the home merchant by the home consumer, and the circulation begins anew.

In the *foreign* trade, the capital goes, 1st, into the hands of the home producer, and thus far stimulates industry at home. 2dly, It is intrusted in the form of produce to the captain or supercargo, who, 3dly, delivers it to the foreign merchant, who, of course, demands a credit, equivalent to the time necessary for the return of his own capital into his hands in his own country. 4thly, The foreign merchant, for this purpose, entrusts it to the foreign purchaser or consumer; who, after some time, returns it, 5thly, into the hands of the foreign merchant; who again, 6thly, invests it with the foreign producer, the farmer or producer of his own country. 7thly, The foreign produce thus purchased, is entrusted, on board the ship; whence, 8thly, it gets into the hands of the home merchant; who sells it, 9thly, to the consumer; who, 10thly, after usual credit, returns it again in the last place to the home merchant.

Adam Smith, Herenschwand, and La Riviere, all agreeing in the general course, vary somewhat in their view of it, from that now given. But from every view taken of it, we may fairly conclude, that the same capital puts in force 2 or 3 times the industry at home when employed in the home trade, that it does when employed in the foreign trade.

4thly. *Comparative importance of the foreign trade and home trade in point of amount.* The country of all others most engaged in foreign trade, and generally cited as an example of riches and prosperity derived from this source, is Great Britain. Let us see what her foreign trade amounts to, compared with her internal commerce.

The war with France has now continued seven years. It be-

gan in 1793. In estimating the value of the foreign trade of Great Britain, and taking the amount of exports as the exponent of it, I shall confine myself to the year preceding the war. Because, the first year of the war evidently sank the amount near five millions sterling below the natural progressive standard; because, in time of war, there is no steady march of foreign trade; the exports involve much of hazardous speculation. Because the custom-house entries are swelled by the amount of exports, consisting of articles consumed in the war itself, and purchased by government for the use of armies and navies; and these entries are gravely brought forward as evidences of the great increase of trade and national prosperity!

I know the objections to the accuracy of custom-house entries, and their official compared to their real value; but they are the best evidence we have; and an error of two or three millions, will make no difference in the present reasoning.

I say then, that the gross amount of the exports of Great Britain previous to the year 1794, *when the nation was fully embarked in the war, never reached* 25 *millions sterling.*

Year.	*Gross amount of export.*	*Balance of trade.*	*Nett customs paid into the exchequer.*	
1792	24,905,200	5,776,618	4,027,230	Upon export
1793	20,390,180	1 542,154	3,978,645	and import.

I state it also, as a calculation well known and generally received in that country, that a merchant's and manufacturer's clear profit is 12 1-2 per cent on his capital, which, on 25 millions, will be 3,125,000*l.* This is paid by the foreign consumer, and the nation gains it. The trade of Ireland that year may be calculated at 3 1-2 millions, on which the gain will be 437,500*l.* So that in the most prosperous year of peace, the clear profit on the whole foreign commerce of Great Britain and Ireland, can hardly be taken at more than 3 1-2 millions sterling!

Let us now see what is the amount of the home trade, or internal commerce; this consists of the amount of agricultural produce, and the amount of manufacturing produce: including woods, minerals and fisheries.

It appears from the first report of the select committee on the waste lands, ordered to be printed December 23, 1795, that there are in Great Britain 73,285,628 acres, of which 51,178,627 are cultivated, and 22,107,000 are uncultivated. The cultivated lands of Great Britain produce a wheat crop of certainly not less than

18 bushels an acre: Arthur Young, a competent judge, states it at 24 for England. Wheat, however, does not, or ought not, to occupy more than one year in four; the others being appropriated to potatoes, rye, barley, oats, beans, peas, turnips, cabbages, carrots, or grasses. If the average crop therefore be taken at 10 bushels, it will be somewhat below the amount. The average price of wheat for December, 1792, according to Young's annals of agriculture, was 6*s*. 1*d*. This will make the average produce of the agriculture of the kingdom 3*l*. sterling per acre; a calculation sufficiently low, when it is considered, that this produce must maintain the farmer and his family, his labourers, his horses: it must pay the rent of the land, the tythe, the parliamentary taxes, and the poor tax. At this rate the gross amount of the annual agricultural produce of Great Britain, is 150 millions sterling: exclusive of mines, fisheries, and woods. As the import of grain is very great, the whole of this amount belongs to home consumption.

The calculations of the statists of that country, are, that the manufacturers and mechanics equal in number the labourers in agriculture. It is not therefore too much to assign to the manufacturing and mechanic labour for the home trade of Great Britain, one third part of the agricultural value, or 50 millions.

Great Britain contains 11 millions of people, Ireland more than three. If the internal trade of Ireland be taken at one tenth of Great Britain, then will the annual circulating wealth of the internal commerce of the British empire, be not less than 220 millions sterling.

This subject may be otherwise considered. The actual expenditure of the rich and poor taken on average of Great Britain, cannot be less than one shilling sterling per head per day, for food, fuel, furniture, and clothing. It is probably much more. But 11 millions of people at 1*s*. st. per head per day, will amount to 200 millions and 3-4: a coincidence of calculation, that gives weight to the principles on which it is founded.

If the gross amount of the foreign trade of Great Britain then be 25 millions, at the same time when the gross amount of the home trade is 200 millions, who can be mad enough to attribute the power and prosperity of that Kingdom to the foreign trade?

Again. The taxes of that country must be bore partly by the foreign, partly by the home trade. Last year (1798) the minister demanded supplies to the amount of 35 millions: the gross receipt of the customs was 5 1-2 millions including export and im-

port. What capital was it that bore the rest? But in fact, the foreign trade bore but about one half of this 5 1-2 millions, for it is the home consumer, not the foreign consumer, that pays the tax on import: that tax, is a burthen not on the foreign, but on the home trade. Of the 35 millions required therefore, the foreign trade of Great Britain did not supply three.

So in 1800, the Custom house produced about six and three-fourths millions. But the interest of the debt that year was *l.* 20,186,507 and the demands of supply for the army, the navy, the ordnance, the civil list, the miscellaneous services, the interest of the loan, &c. as much more. But if the foreign trade can furnish as in this case, but a sixth part of the supplies required, where does the rest come from? Is there any other source but the internal commerce of agricultural and manufactured produce? Take any year of the last half century, and you will find, that the foreign trade has borne but a very small part of the national burthens.

Where then is the great source of wealth, of that powerful and wealthy country? It is in her spirited agriculture: in 100 millions st. of farming-capital, permanently laid out in buildings, in fences, in roads, in canals, in machines. In 50 millions more annually expended in manures, in repairs, in exuberant cultivation. Here is the secret of 24 bushels in England, 16 in France, and 10 in this country. And so in her manufactures; the intense activity and energy, which the high price of living requires from every body in England; the wonderful skill acquired by the division of labour; the great superiority of task work over day labour; and the immense capital under the direction of profound knowledge in the manufacturing machinery of that country, enable her inhabitants to bear the enormous expence of her government.

In France under the old Regime, if a man possest 5000 louis, he bought a marquisate: in England a young man with 5000 guineas would enter as the junior partner of some house of repute. In France, a tradesman scorned to work for the Canaille, if he could help it: in England every tradesman consults the taste of the great mass of customers, the middle and the lower classes of society. In France, accumulated capital was spent; in England it is employed for the most part in begetting capital. In France, trade is disreputable; in England, all kinds of industry, are compatible with the acquirements of a scholar, and the polish of a gentleman.

By the report on the waste lands, 22 millions of acres appear to be uncultivated: of which upwards of 20 millions admit of cultiva-

tion. Suppose being cultivated, the produce per acre might be 5s. sterling. Then would the waste lands of that kingdom become a source of wealth to the nation beyond the profit of the whole foreign trade.

Next to Great Britain, France of all the great European powers has the largest proportion of foreign trade. France contains 131,722,711 acres: that is 130 millions of acres exclusive of roads, &c. The proportion of produce between England and France per acre is as 24 to 16. From the data furnished by A. Young in his tour to France, v. 1 p. 282, 341, et seq. I calculate the gross amount of the produce of lands in France at 30s. sterling per acre, or 200 millions; and as the manufactures of that country are greatly less valuable than those of England, I should not rate the whole amount of the home trade of that kingdom beyond 225 millions, (1792-3). There is no getting at accuracy in these matters; especially situated as I am; but luckily, the principles in question, do not need any thing more than a reasonable approximation to truth.

I have no modern facts as to the Commerce of France. M. Arnould in his Balance du Commerce, states the average exports of France from 1784 to 1788, at 354,423,000 livres; or about fifteen and a half millions sterling; the average for the same period in Great Britain would give sixteen and a half millions. Can the power and prosperity of either country at that period, be ascribed to the merchant's gain of twelve and a half or 15 per cent. on these insignificant sums? ought we not rather to look for it in the excess of industry over expenditure, in the 200 or 225 millions of home trade? Especially when it is considered that immediately previous to the war of 1793, the taxes of Great Britain (exclusive of Tythe, Road, and Poor Tax) amounted to near 20, and of France to 25 millions?

We are surprized at the exertions of Great Britain, and her full equality in power to France, when the population and the territory of the latter country is so much greater. But we shall wonder no longer, when we consider that under the bold expenditure of farming capital in Great Britain, the quantity of agricultural produce of both countries is nearly equal, and the manufacturing produce of the latter country, much greater. Wealth arises from land, and labour, and capital, being employed productively, instead of land being kept waste, labour unemployed, and capital dissipated in fruitless luxury.

But let us turn our eyes to our own country. Our population amounts now (1800) to about five millions. Suppose 5 acres per

head cleared: a proportion not too large, for I know by repeated calculation, that it takes at least three acres to supply the food and drink of a labouring man here, as labourers usually live. Then will there be 25 millions of acres in cultivation, producing an average annual value of 5 dollars per acre, or 28 millions sterling. The produce of timber, lumber, fuel, cabinet-wood, game, &c.—of the fisheries of our rivers and streams—of home manufacture of every description, may be reasonably computed at one fourth more; making a total of 35 millions sterling, for the home produce of the American states.

The last report of the gross amount of foreign trade (our exports) was 61 millions of dollars, of which 33 millions was the value of produce of foreign nations. Our own foreign trade then, amounted to 28 millions of dollars, or about six and one-fourth millions sterling; while the gross amount of internal produce is nearly six times that sum.

Such was the state of things about 1798, 1799.

Hence it appears, that whether we look at England, France, or America, the gross amount of the home trade is prodigiously beyond that of the foreign trade; which has no pretensions to be regarded as the great source of national wealth.

5thly, *The lands of America stand particularly in need of capital.* When I state this, I am not an advocate for colonizing the wilderness two thousand miles from our sea-board. Our frontier is already extended beyond all reasonable bounds. But the space of territory we might prudently populate, is not half peopled* or near it. Of the populated part, the lands are not half cleared; of the cleared lands under cultivation, not one acre in a hundred is half cultivated. I am afraid I over calculate, when I rate an average wheat produce at 10 bushels, most certainly not half the average of England. 1 Young's French Tour, 343, 431, gives the details that shew the superior produce of England over France, to be owing to the greater agricultural capital of the former nation. Under these circumstances, it is not prudent to foster, and encourage the investment of capital in foreign trade.

6thly, *The capital of the foreign trade, is more precarious than that of the home trade.* Precarious from the hazard of storms, the hazard of war, the hazard of failure of a foreign debtor, living at a great distance and under foreign jurisdiction. The very idea

* New England, on 72,000 square miles, contained 1 1-4 millions of people in 1800: not 18 to a mile.

of insurance companies is commercial. Hence, if the same capital could be employed to equal profit, national and individual at home, it were better so employed than abroad.

Suppose a ship lost by storm, by depredation upon our commerce, by unjust adjudication, the value is gone from us, it is annihilated. It is true the merchant may lose nothing—he can generally lay his losses on the consumer. The price of insurance is part of the price of the commodities insured. Suppose the value of a cargo laid out on a plantation, in building, fencing, making roads, manuring, &c. a storm may destroy the crop, as well as the ship, but the produce of the year only is lost: the capital still remains, permanent and productive.

7thly, *The merchant, and all the people directly employed by him, rank among the unproductive classes of society.* The farmer, the wood-cutter, the miner, the manufacturer, the fisherman, employs his capital and labour in producing substantial riches, some commodity of value. I know this has been doubted as to the manufacturer; but it is, in my opinion, absurd to say that a millwright, a saw-maker, an engineer, and all who convert raw materials into labour-saving articles, are not of the productive class; and eminently so. This *may* be occasionally the case with the persons in question, but we are not talking of exceptions to a general rule, but of the rule itself.

The merchant, the agent, the factor, the retailer, the clerk, the captain, the seamen, are employed in arranging, assorting, dividing, transporting what has been already produced by the capital and labour of others. If produce be (as it clearly is) the real, the only riches of a country, we ought to aim at encreasing it, and encourage (if the system of encouragement *be* adopted at all) the employments that are productive, rather than those that are not so. All these people are usefully employed under the system of commerce; but it forms a drawback to that system, that so many persons are unproductively employed. I am aware of the objection, where will you find a market? There is never want of a market in a new settlement: you can *make* your market, by manufacturing a great part of what you buy. When provisions become a drug, manufacture starts up, and population abounds. This is the most desirable and most permanent order of things, because nature herself has pointed it out.

8thly, *Mercantile success tempts to imprudent expenditure and speculation.* It is no slight objection, that, while by the peaceful

labours of agriculture, gains can be made but slowly, gradually, and by the regular exertions of habitual, wholesome industry—the commercial speculator, often gets rich by accident, by imprudent and unfair venturing, by sudden exertions. Wealth thus suddenly obtained, is, in many respects, detrimental to the community. It operates as a lottery: it tempts capital into trade beyond prudent bounds: it entices to unjustifiable boldness: it too often introduces ostentatious luxury, not warranted by the sober dictates of moderate and regular gains.

9thly. *The merchant is of no country.* That is, he is not necessarily attached to any. His connections are as much out of his native country, as in it; he has frequently inducements to sojourn abroad: the domicil of nativity, and the mercantile domicil, are so often different, that the distinction with the privileges belonging to it, are recognized and settled in the laws of all commercial countries. His property is moveable, transportable; that is his country, where his interest calls him, where his means of gain have located his investments. Where the treasure is, there will the heart be also.

Nor is it to be expected that mercantile speculations, will be voluntarily regulated by national expedience. It is the merchant's business to attend to his own concerns; let the governors of the nation attend to the national concerns. Of what consequence is it to the merchant, at what expense the commerce of his country is supported? the nation, the home consumer, pays for all. Increased expences are always and reasonably laid on the price of the commodity: the merchant therefore cares little about them, provided they are common to the body of merchants. It is his interest to magnify the great importance of foreign commerce; to obtain protection for it though at ten times its value to the nation; to engage government on his side; and this unfortunately he is generally enabled to do, by his importance to revenue, to loans, to banks, to finance operations; men in power and merchants are always allies. However clear sighted as an individual, the *statesman*, sees nothing but revenue. The merchant sees and steadily pursues his own interest. Is not this too natural to be blameable?

Moreover, the merchant's occupation is always liable, not only to the temptation of illicit pursuit, but to the jealousies of foreign mercantile interests, to quarrels and controversies involving national feeling. Let the reader reflect on the cover our professed neu-

trality has afforded, during these seven years of continental war (1793 to 1800) for illicit trade, for jealousy, for complaint, for attack, for real and for pretended retaliation.

From all these objections, the home trade is free. The home trader is fixed; he has his all at stake in the country he lives in; he can have no interest out of it; he can be counted upon; foreign interests, and foreign governments have no hold on him; he has neither the temptation, the means, the opportunity, or the inclination of doing national mischief, or giving cause for national offence, or giving rise to national quarrels; in the common course of things, and necessarily, his interests and his country's interests are coincident; his gains are his country's gains; whatever capital he employs, stimulates not foreign but home industry; it is employed in, and upon, and for, his own nation and national territory; all his affections and associations are connected with home, and centre there.

10thly, *Commerce has never paid the interest of the expensive wars it has induced.* It is useless to examine this question by the example of many of the maritime countries of Europe. The inferences from British facts, will suffice: *ex uno disce omnes.*

Sir John Sinclair states the commercial wars of George II. and George III. (2 Hist. of the public revenue, 99) as follows: war of 1739, 46,418,689*l.*: war of 1756, 111,271,996*l.*: American war, 139,171,876*l.*: Russian and Spanish armaments, 2,311,385*l.*: Total, 299, 173,946, or, in round numbers, 300 millions sterling.

Government has borrowed at rates from 4 1-2 to 5 1-2 per cent. Now I should be glad, if any advocate of the commercial system could point out to me, when Great Britain ever made, or when she is likely to make 15 millions' profit on a year's export!

But; the fifteen million annual taxes thus permanently saddled on the country in support of the commercial system, is not all. On the 20th of Dec. 1792, parliament granted as supplies for the navy, for 1793, somewhat above 4 millions sterling. A sum that has annually encreased ever since that time: but I confine myself to the peace establishment. I well know that a navy is necessary to Great Britain as a means of defence, but not such a navy: Her navy is not employed in home defence, nor a fourth part of it. The East Indies, the West Indies, the Mediterranean, the whole world dotted over with her commercial colonies, call for it. I am greatly within bounds, if I state, that two of the four millions is to be regularly charged to her commercial system. Look into the mis-

cellaneous services for the same year, and you may pick out about half a million more that goes to the debit of the same account. Admirable system! which purchases an annuity of 3 millions and a half at the certain expence of an annuity of 17 millions, and the probable expence of as much more. For war and commerce are steady companions.*

I say nothing as to the East India Company. That concern is insolvent.

Much indeed of all this expence has been owing to the system of colonization: but colonization is the immediate offspring of foreign commerce, whose life and soul on the modern system is monopoly. I am decidedly convinced that colonies are millstones round the neck of every European nation that has fostered them; the very worst part of the system of Commerce. I am sorry to say, that, much of the calculations which demonstrate this, are applicable to the conduct of the United States, in their mode of peopling the wilderness of America. The frontier is extended till the strength of the country is weakened. I almost doubt if we are at this moment so competent to meet hostilities, as at the beginning of the revolutionary war.

11thly, *The modern system of foreign commerce, is the most productive source of human misery.*

Almost all modern wars are *purely* commercial: *none* of them are free from commercial motives and considerations. Would to God the means existed of, easily, cheaply, and surely destroying a ship of war! The quarrels of nations are no longer local. Sting the pride, or touch the interest of England or France, and devastation extends at once to every quarter of the globe!

It was not better two centuries ago, when the colonizing and commercial system *began* to rage. Turn your eyes to the conduct of the Spanish in South America—the Portuguese in Africa—the British and Dutch in the East Indies—to the slave trade, that disgrace of humanity, and say if this position requires farther proof.—

12thly, *The most flourishing, populous, and best cultivated parts of Europe, are not maritime or commercial.* I except Holland; that is not a country but a city of merchants; driven into the sys-

* This is not much unlike the infatuation of Great Britain as to the woollen trade. It seems to me *proved*, that the whole commercial profit of that avaricious manufacture, has been taken from the pocket of the English farmer, who has been prohibited from exporting his wool. But the farmer is an animal, whom the merchant and the manufacturer can shear with impunity.

tem of foreign commerce and the carrying trade by their maritime situation; they had no other resource, for they possess comparatively no territory.

I select the following from Jameson's Political Geopraphy, which I prefer to Zimmerman's. The first table contains the maritime and commercial nations, with the inhabitants upon a square mile. The second table contains the states which enjoy little or no foreign commerce, with the inhabitants on a square mile in those states.

Table First.		*Second Table.*	
Great Britain and Ireland,	111	The whole of Germany,	135
Great Britain, - - -	119*	Palatinate of the Rhine with Bavaria,	134
England and Wales, -	150†		
Ireland, - -	109	Electorate of Saxony,	150
Scotland, - -	59	French acquisition on the left bank of the Rhine,	200
France, - -	157‡		
Spain, - -	70	Piedmont, - -	240
Portugal, - -	72	The Milanese and Austrian Italy, - -	240§
Denmark, - -	13		
Sweden, - -	14	The Pope's State,	160
European Russia, -	17	Republic of Venice,	193.

To which it will not be unfair to add the empire of China with no foreign trade, but permitting every nation on payment of duties to fetch away her Commodities, 333 per square mile. To say nothing of the inland country of India, equally populous, by the cultivation of the earth, and internal manufacture.¶

I may assert further, as a known fact to European travellers or readers of travels, that the public monuments of art and apparent wealth of the second table, exceed the first.

13thly, *The Commercial nations have uniformly fallen before the Agricultural nations.*

* Zimmerman.

† This is far too great, being calculated on a surface of 79,712 square miles, whereas the report of the Committee of waste lands, before quoted, make a surface of seventy-three and one-fourth millions of acres, or about 114,500 square miles, or about 106 to a square mile. There are in fact not so many. Distribute 11 millions of souls over 114,500 square miles. All the preceding calculations are therefore too high for the same reason.

‡ This is too high, being calculated on a surface of 157,924 square miles, whereas Neckar and Young allow 205,816 square miles to old France.

§ Young states the Milanese at 354 per square mile.

¶ Inland towns of 2 or 3 millions of people, have not been uncommon in India. Visapour, an inland town, contained at one time near a million of houses. See Captain Moore's narrative.

Antiently, Tyre, Sidon, Carthage, before the Macedonians and Romans: Athens subdued by Lacedæmon: Corinth, Syracuse, Alexandria, by the Romans: Byzantium, by the followers of Mahomet. Where are Venice, Geneva, the Hans Towns, Holland? In commercial nations, surplus wealth is mostly expended in articles of luxurious consumption, *quæ ipso usu consumuntur*, and yield no profit.

In agricultural countries, a far greater portion is spent in substantial improvements on estates; in luxuries perhaps, but in permanent and productive luxuries. Hence provisions are cheap, population thick; the raw materials of warfare easy to be found.

What then are we to conclude? Prohibit commerce? Refuse protection to our citizens engaged in lawful occupations? Are not our merchants as much entitled to defence as any other class? No. Prohibit nothing: but protect no speculation, no investment of capital at an expence beyond its national value.

If wars are necessarily attendant upon commerce, it is far wiser to dispense with it; and imitate the nations who have flourished without foreign trade. Those who want your commodities will fetch them away. If they will go to China for tea-cups, they will come to America for bread. But if your merchants *chuse* this mode of investing their capital, do not forbid them. Let them do it like other adventurers, at their own risk. While it is profitable, let them pursue it; but should the quarrels of other nations, render it unprofitable, do not bolster it up by the bounty of protection, at an expence of ten times its value, and at the hazard even of national existence. Foreign trade with peace is desirable, but not so if it be the parent of war.

All wars should be defensive wars, and those only: *pro aris et focis*, for our houses and homes. Can we call a war undertaken to protect a mercantile speculation 5000 miles off, a *defensive* war?

At any rate, sit down and count the cost. If the expence of fencing my garden lot against depredation, will exceed the value of the ground, and involve me in a law suit into the bargain, I had better let it remain uncultivated.

If any profession is to be festered, let it be the tiller of the earth: the fountain-head of all wealth, of all power, and all prosperity. Improve your roads, clear your rivers, cut your canals, build your bridges, establish schools and colleges, facilitate intercourse, and diffuse knowledge of all kinds. No fear but if you raise produce and people, they will find their market, either at home or

abroad. It will soon be discovered, what articles are most wanted, what are most profitable, and these will be supplied. On this simple plan of *home defence*, wars may be avoided, for what nation would or could invade this? But on the system of foreign commerce, the misconduct of your own, or of foreign merchants, will forever make peace insecure. Even your honourable successes will be causes of jealousy to other nations whose councils are guided by mercantile policy, and the maxims of the counting house. On that system, wars, debts, taxes, and despotism will be inevitable.

T. C.

SUGAR FROM BEETS AND GRAPES.

I observe in some late numbers of the Moniteur, that to April 1812, (Monit. of 19th April of that year) two hundred and fourteen licenses had been taken out for the manufacture of sugar from beets in France; hence I presume it must be, not only a practicable, but, in that country, a profitable concern, or the tax would not be paid for the license.

Klaproth, who repeated Achard's experiments on this subject at Berlin, procured from 25 beet-roots, which, when topped and scraped, weighed 32 1-2lb. 19 3-4lb. of juice by expression. The squeezed residuum was boiled in water, and again pressed. The liquors added together were boiled to a syrup, strained and slowly evaporated. The raw sugar amounted to 2lb. and 12 ounces.

The king of Prussia, in the fall of 1799, appointed a committee to repeat these experiments. They did so. From 1500lb. of beet-root, they produced 398lb. of syrup; which yielded 57lb. of tolerably white powder sugar.

I mention this, not to recommend the substitution of beets for the sugar cane, though I hope we shall soon substitute Louisiana for the West Indies; but to suggest a query, whether the expressed juice of beets, would not be a profitable article to distill?

The French also, procure sugar from the syrup of grapes. (Appercus des resultats obtenus, &c.) "Practical view of the "results obtained from the syrup and conserve of grapes in France, "during the years 1810 and 1811, by M. Parmentier, published by "order of government—price 5 francs."

BURNING GLASSES.

A remarkably large parabolic lens was recently purchased at Vienna, for the French government. It was made at Gratz, in Styria, by Rospine, a celebrated mechanist, for some alchemist. It was not cast, but softened by heat and bent over a parabolic mould. Several pieces were broken before he succeeded; so that it cost originally from 800 to 1200 guineas. It is three feet three inches in diameter, and of eight feet four inches focus; composed of 2 pieces of glass united together by an iron hoop so as to form a hollow vessel, capable of holding eighty or ninety quarts of spirits of wine. M. Jacquin, of Vienna, and several men of science, who witnessed the experiments, declared, that it burned a diamond in a few seconds, and fused platina in a few minutes. A button of platina weighing twenty-nine grains, was melted by it, and made in part to boil. The diameter of the focus does not appear to exceed four lines. It weighs 550lbs. avoirdupois. *London Pap.*

This seems to me to be an improvement in the manufacture of lenses.

Of burning glasses. I have examined the question concerning the burning glasses of Archimedes. It rests upon vague and second hand authority. Polybius says nothing of it: nor Livy, nor Plutarch. There is not authority sufficient for the story of the burning glasses of Proclus. Such feats may have been done; there is no clear testimony to warrant our assertion that they were done.

In modern times, the glasses of Villette, Tchirnhausen, Buffon, Trudaine, and Parker are well known. That of M. Trudaine made at the expence of 1000*l.* sterling and presented by him to the Academy of sciences was constructed somewhat on the principle of the above mentioned lens. Two concave glasses, joined by their edges so as to present a cavity of 4 feet diameter, filled with 140 French pints of spirit of wine. It was broken by accident soon after it was presented. In the glass above mentioned made at Vienna, the improvement seems to be, the bending the plane glasses by gradual heat, over the mould.

Parker's lens, made at the expence of 700*l.* sterling, was sold by him for less than prime cost, and carried out by Lord Macartney as a present to the emperor of China, to be placed among the toys of that childish court. This was clearly the best lens ever constructed; and it is a disgrace to the nation, that Mr. Parker

was obliged so to dispose of it; and that a philosophical instrument, the finest of the kind the world had yet seen, should have been so egregiously thrown away.

The blow pipe, supplied with hydrogen and oxygen gasses, affords a degree of heat nearly equal to the best burning glass.

Dr. Bollman, who has so ably discussed (but not exhausted) the question of banks and paper money, has succeeded in manufacturing Platina into bars, wire, spoons, and crucibles. I do not know his process, which he has a right to reserve for his own emolument. The common method is, to dissolve the platina in nitro-muriatic acid, to precipitate it with sal-ammoniac; to redissolve and reprecipitate this orange-coloured oxyd of platina; to put it when dry into a crucible without addition, unless, perhaps, of lamp black. It is exposed to a strong heat till it becomes agglutinated in a spongy mass. This spungy mass while strongly heated, is pressed down with as much force as the crucible will admit, and this is continued till the parts approximate. The mass is then taken out, and hammered gradually and gently, till it unites in an uniform mass, and is then rolled. This, I say, is the common method.

Dr. Bollman's platina, is of specific gravity 19,7 the same as gold. Mr. Cloud, of the mint, to whom we are indebted for much useful and curious knowledge on platina, and the methods of purifying it, has freed it from the iron, palladium, iridium, and rhodium, so that his specimen of *pure* platina, is upwards of 21 spec. grav. I give this notice with great satisfaction, in hopes, that Dr. Bollman may benefit by it, as well as the public. He is entitled so to do.

The same gentleman has also succeeded, in a small way, in purifying the pyroligneous acid, so as to make it a substitute for distilled vinegar: a manufacture, attended, as I hear, with great success in France. In England, the pyroligneous acid (the acid liquor poduced from wood by distillation) has long been applied in the large way, to the making of iron liquor, for the dyers and prin ters of London and Manchester.

CAST IRON.

It has been mentioned that cast-iron, when at a certain degree of heat, may be cut like a piece of wood, with a common saw. The discovery was announced in a letter from M. Duford, director of the iron-works at Montalaire, to M. D'Arcet, and published in the Annales de Chimie. This experiment was tried at Glasgow, on Monday se'nnight, with complete success, by a gentleman of the philosophical society there, who, in presence of the workmen belonging to an ironmonger, cut with the greatest ease, a bar of cast-iron, previously heated to a cherry red, with a common carpenter's saw, in the course of less than two minutes. The saw was not in the least injured by the operation.

NOTICE TO CORRESPONDENTS.

I have received a letter signed O. E. on turpike roads. The only reason why it is not published in the present number, is, because I wish to say something on the subject myself, in addition to O. E's paper, for which I thank him.

An accident has prevented my inserting the analysis of the limestones, transmitted to me by Judge Peters. I have to repeat the experiments in consequence of this. I will endeavour to insert them in the next number.

A correspondent of the Emporium enquires, whether and when it is intended to give papers on the dying of cotton. If I continue to conduct this Emporium, I shall endeavor to present the information I have collected, in a way as little desultory as possible. I know that the generality of readers, love to see a pamphlet that treats on twenty subjects at once; but as I really mean to make this, if I can, a collection worth preserving, I will not go on in that way, by which no connected information can be given. To make a medley of this kind, I have nothing to do but to mark with my pencil the essays I choose to pillage from British compilations, and give the books to the printer. I will not do this.

I propose to draw up regular, connected essays on manufacturing processes; composing, compiling, selecting, abridging, and arranging, in the best manner I am able. This trouble I might easily save myself by pursuing the common method, and make

the book in all probability more popular. But it would neither be useful to the public, nor creditable to myself.

Two thirds, or thereabout, of every number shall be devoted to essays on the manufactures connected with iron, steel, lead, copper, tin, silver, gold, and the other metals and semi-metals. I will then proceed to the subjects of bleaching, dying, and printing; the making of colours and of drugs; to brewing, distilling, and other subjects of manufacture, concerning which I have already made my collections. From one half to one third of each number shall be devoted to miscellaneous articles. Like other labourers in the same field, I shall depredate in all quarters, and borrow where I can; still, the work shall bear evident marks of my own labour upon it.

T. C.

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IRON.

(Continued from page 155.*)*

19thly. I say nothing respecting the effect (if any) produced by the decomposition of the carbonic acid gas that is formed by the carbon of the coal, uniting to the oxygen of the ore, and of the moisture. I am not equal to the investigation, for want of more precise knowledge of fact. I must say the same as to the effect produced by the carbonic acid gas driven off from the limestone, to the amount of 44 per cent. in weight. I do not know that this is again decomposed. I am fully aware of M. Clouet's and Mr. Mushet's experiments, and I know too, that carbonic acid gas contains 28 3-4 per cent. of pure carbon or charcoal, but I cannot yet apply them to a smelting furnace. I shall remark upon this when I come to the subject of steel. For the same reason I leave untouched any chemical theory as to the combinations that may be formed by the Potassium of the charcoal ashes, or by the Calcium of the lime, the Aluminum of the clay, or the Silicum of the siliceous earths. I subjoin Mr. Davy's re-

marks, but I am not at present qualified to apply them to practical purposes.

"Iron is capable of combining with Potassium and Sodium; these alloys are more fusible and whiter than iron, and effervesce copiously in water. There is great reason to believe that alloys may be formed of iron and the metals of the earths. *Cast iron*, which is produced by fusing iron ores with pitcoal, during its conversion into malleable iron, affords but one fourth of its weight of a glass, which consists of silex, alumine, lime, oxide of iron, and oxide of manganesum. In the process for reducing cast iron into malleable iron, called *blooming*, the iron, after being fused in a forge by a fire of charcoal, is hammered, whilst in a soft state, on an anvil, by a large hammer worked by water; a vivid combustion, which seems to be connected with the formation of the glass and the oxides, takes place on the surface of the mass: that the earths are formed by the oxidation of metals combined in the cast iron seems probable from the circumstance of the combustion; and the idea is confirmed by the distinct metallic character of cast iron; it is white, crystallized, and has all the appearance of a perfect alloy. Specimens of cast iron usually contain likewise sulphur and carbon."

20thly. I close these remarks by the following quotation from Mushet—5 Ph. Mag. 366.

On the relative Proportions of Coals and Iron-Stones used at the Blast-Furnace, and of their proper Application to Use. By Mr. David Mushet, *of the Clyde Iron-Works. Communicated by the Author.*

IN the smelting operation a just proportion and association of materials and mechanical construction ought to be blended in order to produce the best possible effects. Under the former, are comprehended the cokes, ironstone, limestone, and blast; by the latter is understood

the furnace, the power of the blowing-machine, or the compression and velocity under which the air is discharged into the furnace, and the genius or mechanical skill of the workmen. According to this division, I shall endeavour to point out the very various effects which disproportion in any case produces, and *vice versa.*

In the preceding papers, the coal and iron stone have been traced through their various stages of preparation, and that stage pointed out in which they were most suitable for the profitable manufacture of the metal. It will be necessary to carry along with us this fact, that in the exact proportion which the quantity of carbon bears to the quantity of metal in the ore, and its mixtures, so will be the fusibility, and of course the value of the pig-iron obtained. The importance of this truth will still farther appear, when we consider the very various qualities of pit-coal, the different proportions of carbon which they contain, and the various properties attached to every species of this useful combustible.

Among the many strata of coal which I have distilled, some I have found to contain 70 parts in the 100. This large proportion is peculiar to the clod-coal, used at some of the iron-works in England, and justly preferred, for the purpose of manufacture, to the purest and hardest variety of splint-coal. The latter I have found to average from 50 to 59 parts of carbon in the 100; and the soft, or mixed qualities of coal, from 45 to 53 parts. Such various proportions of carbon plainly point out that the operations to be followed at each individual iron-work ought not to rest upon precedent, unless borrowed from those works where exactly the same quality of coal is used. This analysis also, lays open part of the source from whence originates the widely different quantities of metal produced *per* week at various blast-furnaces, and the great disproportions of ore used to different coals.

Experience has shewn that the three qualities of coal just mentioned, will smelt and give carbonation to the following proportions of the same species of torrefied iron-stone :—

112 lb. of clod-coal cokes will smelt - -	130 lb.
112 lb. of splint-coal cokes will smelt - -	105 lb.
112 lb. mixed soft and hard coal cokes will smelt	84 lb.

Let the iron-stone be supposed in the blast-furnace to yield 40 *per cent.* then we find that the 1-20th of a ton of the respective qualities of cokes will smelt and carbonate the following proportions of iron, *viz.*—112 lb. clod-coal cokes, 130 lb. iron-stone, at 40 *per cent.* = 52 lb. iron; 112 lb. of splint-coal cokes, 105 lb. of the stone = 42 lb. of iron; and 112lb. soft and hard coal cokes, 84lb. of the iron-stone = 33, 6 lb. of iron. We then have for the quantity of metal produced by one ton of each quality of cokes :

Clod-coal	52	× 20 =	1040 lb.
Splint ditto	42	× 20 =	840 lb.
Mixed ditto	$33\frac{6}{10}$	× 20 =	702 lb.

This furnishes a datum, whereby we easily obtain the quantity of the various cokes necessary to produce 1 ton of carbonated crude iron by common proportion : for if 1040 lb. of metal are produced by 1 ton, 2240 lb. of clod-coal cokes, the quantity of the same cokes requisite for the production of 1 ton, or 2240 lb. of metal, will be :

			T.	*C.*	*Q.*	*lb.*
		4824 · 6 lb. =	2	3	0	8
Splint coal cokes	840 : 2240 : : 2240 :	5973 · 3 lb. =	2	13	1	9
Mixed ditto	702 : 2240 : : 2240 :	7147 · 5 lb. =	3	3	3	7

If to the quantity of cokes necessary to manufacture 1 ton of crude iron, we add the quantity of volatile matter driven off in the process of charring, which may be thus estimated upon the average of each quality :—

Clod coal	$\frac{3}{8}$ or $37\frac{1}{2}$ *per c.*	produce in cokes	$\frac{5}{8}$	*a* $62\frac{1}{2}$ *per c.*
Splint coal	$\frac{4}{8}$ — 50	————————	$\frac{4}{8}$	or 50
Mixed coal	$\frac{5}{8}$ — 62,5	————————	$\frac{3}{8}$	— $37\frac{1}{2}$

Then, for the quantity of the respective coals used in the raw state, we have the following results in proportion:—

			T.	*C.*	*Q.*	*lb.*
Clod coal	$5:4824\cdot6::8:7719\frac{3}{4}$	=	3	8	2	19
Splint coal	$4:5973\cdot3::8:11946$	=	5	6	2	18
Mixed coal	$3:7147\cdot1::8:19158\frac{2}{3}$	=	8	11	0	16

These great disproportions of quantity, used to fabricate 1 ton, or 2240 avoirdupois pounds of the same quality of crude iron, will convey a striking and impressive idea of the multifarious qualities of coal which may be applied and made to produce the same effects. It should also convince the manufacturer that the study and analysis of his own materials is the first and radical approach to true knowledge, and certainty of operation. Divest him of this knowledge, and view him guided by the *customs* and *rules* prevalent at another manufactory, where the coals and ores may be as different as has been already mentioned, and we will no longer wonder at the uncertainty of his results, and the numberless errors of his direction.

Before I enter into the practical discussion of the application of coal, I beg leave to indulge myself in the following calculations:—We have already seen that the production of 2240 lb. of carbonated crude iron requires 4824 lb. of clod-coal cokes; these may be averaged to contain 4·5 *per cent.* of ashes, which, deducted from 4824, gives 4607 lb. of carbon used for 1 ton of metal: this sum, divided by 2240, farther gives, for 1 lb. of cast iron thus manufactured, 2·056 lb. of carbon.

We next find that 2240 lb. of the same metal requires of splint-coal cokes 5973·3 lb.; we farther find, from a table of the analysis of coal, furnished in a former paper, that 100 parts of the raw coal contained 4·2 parts of ashes. As it is there stated to lose 50 *per cent.* in char-

ring, 100 parts of cokes will contain 8·4 of ashes; and 8·4 *per cent.* deducted from 5973·3, gives 5472 lb. of carbon. This again, reduced by 2240 lb. gives for each lb. of metal manufactured, 2·442 lb.

Again, 7147·1 lb. of cokes produced from soft mixed coals are consumed for every ton of 2240 avoirdupois pounds of crude iron produced; every 100 parts of the same coals contain 3·3 parts of ashes; and 100 parts of cokes contain nearly 6·5 *per cent.* of ashes, which, deducted from 7147·3, gives 6672·6 of carbon, which divided by 2240, gives, for the quantity used for 1lb. of cast iron, 2·978 lb.

From these calculations it appears, that 2240 lb. of carbonated iron, requires of carbon from clod-coal 4607 lb.; of carbon from splint-coal, 5472 lb.; and of carbon from mixed coal, 6672 lb.: that 1 lb. of carbonated iron requires of carbon from clod-coal cokes 2,056 lb.; from splint, 2,442 lb.; from mixed, 2,983 lb.: and that carbonated crude iron may be obtained when widely different quantities of carbon have been consumed.

In seeking for a solution of the latter fact, we must have recourse to the different degrees of inflammability of the carbon, according to the various laws of continuity imposed upon it in its fossil construction. It can easily be conceived, that, owing to this structure, and the nature of the interposed ashes, the particles of carbon of some cokes will be more easily oxygenated than those of others; in the same way that we find splint-coal, when exposed to ignition in contact with open air, affords 1-3d of more cokes than are obtained from soft mixed coals, though the latter, when distilled, yields more pure carbon than the former.

By experiment it is proven, that 100 grains of carbonic acid gas is composed of 72 parts of oxygen united with 28 parts of carbon: if the quantity of carbon of clod coal,

viz. 2·056 lb. used for the manufacturing of every pound of cast iron is reduced to grains, we will find it to consist of 14392 grains; this, divided by 28, gives the acidifiable principle of $514 \times 100 = 51400$ grains of carbonic acid gas;* hence, as 1 cubic foot of this gas, at 29·84 of barometrical pressure, and 54·5 of temperature, weighs nearly 761 grains, we find, that in the formation of every pound of cast iron $\frac{51400}{761} = 67{\cdot}54$ cubical feet of carbonic acid gas will be formed, and in the production of 1 ton of metal, the astonishing quantity of 151289·6 cubic feet. This quantity, however incredible it may seem, is only what would be formed under the above pressure, and at the above temperature: when we take into the account the high temperature at which the decomposition and recombination are effected, with the consequent increase of elastic force and of volume, our ideas are almost unable to commensurate the sum of the gas hourly formed, and thrown off, ignited to the highest degree of heat.

If the same mode of calculation be adopted with the other qualities of coal, we shall have the following results:—

For the splint coal 2,442 lb. or $\frac{17094}{28} = 610{,}5 \times 100$

* This is supposing, for the moment, that the whole of the carbon is oxygenated, either by the oxygen contained in the ore, or obtained from the discharging-pipe by the decomposition of the atmospheric air; this, however, is not strictly true, as the metal takes up a small portion, by weight, of the carbon; and when, by accident, moisture has been introduced into the furnace, either through the medium of the blast, or of the materials, its decomposition furnishes a portion of both oxygen and hydrogen, which may dissolve, and also carry off, a part of the carbon. Atmospheric air being found to hold water in solution, a small quantity of hydrogen will, even in the driest weather, be present in the blast-furnace. M.

= 61050 grains of carbonic acid, which gives $\frac{61050}{761}$ = 82,85 cub. feet for 1 lb. and 82,85 × 2240 = 185,584 cub. feet for 1 ton. For the mixed coal or 2,983 $\frac{20881}{28}$ = 710 × 100 = 71000 grains carbonic acid; that is, $\frac{71000}{761}$ = 93,3 cubical feet for 1 lb. and 93,3 × 2240 = 208,992 cubical feet for 1 ton. By the same calculation we may attain a pretty accurate notion of the quantity of atmospheric air necessary to produce 1 lb. or 1 ton of cast iron; an average of the three varieties of coal will be sufficiently accurate for this purpose; thus $\frac{14392 + 17094 + 20881}{3}$ = 17455$\frac{2}{3}$ or 2,4935 lb. of carbon are consumed upon the average of each pound of pig iron: this is found to produce of carbonic acid gas $\frac{17455\frac{2}{3}}{28}$ = 62·341 × 100 = 62·30041 grains; which again divided by 761, the grains in one cubic foot, gives 81·86 cubic feet for the gas discharged in manufacturing one pound of cast iron. As carbonic acid contains, as has already been noticed, 72 parts of oxygen in 100, then we have for the quantity of oxygen gas 100 : 72 : : 62300·41 : 44856·29 grains oxygen gas; and as, at the ordinary temperature and pressure of the atmosphere, a cubic foot of oxygen gas weighs 591 grains, we find 44856·29 divided by 591 = 75·89 cubic feet of oxygen gas necessary to form the acidifying principle of 81·86 cubic feet of carbonic acid gas; and that the same quantity of oxygen gas is necessary to the production of one pound of carbonated crude iron. This leads us to the following statement for the quantity of atmospheric air used during the same operation; first premising that the constituent parts of atmospheric air are nearly 73 of azote and 27 of oxygen gas; of atmospheric air then necessary, we have 27 : 100 : : 75·89 : 281 cubic feet.

I shall now proceed from mere calculation to matter of fact, and attempt to prove the correctness of the former by the approximation of the latter to its results. Let a blast-furnace be supposed to produce 20¼ tons of pig-iron *per* week, = 45360 avoirdupois pounds; this, divided by days, hours, minutes, and seconds, gives *per* day 6480 pounds, *per* hour 270, *per* minute 4½ lb., and *per* second 525 grains.

From this it is evident that 1 lb. of cast iron is produced in $13\frac{33}{100}$ seconds: experience has shewn that a blast-furnace, producing, in any of the above periods, the respective quantity of metal, requires a discharge of air *per* minute nearly equal to 1350 cubic feet; this, divided by 4,5 lb. the quantity produced *per* minute gives, for 1 lb. iron, 300 cubic feet. The quantity, by calculation, we have seen to be 281 cubic feet—difference 19: a sum no way considerable when we reflect upon the inequality of the movements of a blowing machine, and when it is recollected that some allowance ought also to be made for what air may pass through the furnace undecomposed, or may be lost at the place of entrance.

From this coincidence of theory with practice, we cannot help admiring the rigorous principles on which the Lavoiserian system is founded; nor are we less pleased to find, that, small as the operations of the chemist may be, yet they are a just epitome of what takes place in the philosophy of extensive manufactories. The following table exhibits the quantity of carbon which may be used upon an average, with the relative quantity of carbonic acid formed, and air used:

In the manufacture of	1 lb.	—	1 ton of iron,
The pure carbon requisite is	2·49	—	5585·44 lb.
Carbonic acid formed -	81·86	—	183366·40 cub. feet.
Oxygen gas used -	75·89	—	169993.60 cub. feet.
Atmospheric air employed	281·00	—	629440·00 cub. feet.

From the foregoing particulars upon coal may be learned how much is dependent upon the native construction of coal and its constituent parts; I shall next advert to the effects produced by its improper preparation.

When coals intended for the blast furnace are sufficiently charred, they ought, in point of colour, to be of a silver grey; their fracture will appear lamellated and porous if splint coals have been used; softer coals form themselves into branches slightly curved, and, when properly prepared, are always very porous. I have frequently found that the better the cokes were charred, the more water they will absorb. Coals half burnt do not take up half so much water, because their fracture continues in part to be smooth and less porous than when thoroughly burnt.

When half prepared cokes are introduced into the furnace, the metal formerly carbonated will lose its grey fracture, and approach to the quality of oxygenated iron. Their presence is easily detected by the unusual quantity of thick vapour arising along with the flame. Besides, the water and sulphur, which raw coals introduce into the furnace, and which always impair the quantity of carbon by the various solutions effected by the presence of oxygen, hydrogen, &c. the fitness of the coal for combustion, and the support of the ore, is much diminished by this second course of ignition and disengagement of bitumen. The pressure of the incumbent ores also, fracture and reduce the cokes into small pieces, which produce a considerable portion of coke-dust; this is partly carried to the top of the furnace before the blast; sometimes below it appears in immense quantities, ignited to whiteness, and liquid as sand. Coal thus detached from the mass, exposed to the action of a compressed current of air, is unfit for conveying the carbonic principle to the metal; and as it frequently belongs to the just proportion of charcoal

necessary to smelt the ores, and to carbonate their iron, its loss must be felt, and the quality of iron impaired.

When cokes of any quality are exposed to a moist atmospheric, so as to absorb water, their effects in the blast-furnace become much reduced, and the presence of the water is productive of the most hurtful consequences in the production of carbonated crude iron. I have found, by repeated experiment, that 1 lb. of well prepared cokes will, when laid in water, take up 1¾ ounces in the space of half an hour; at this rate, a basket of cokes weighing 80 lb. saturated with water, will contain 140 ounces of water, or 8 3-4ths lb. If the charge contains six baskets, then we see that upwards of 50 lb. of water is introduced regularly along with the charge, furnishing an additional quantity of oxygen equal to 42 1-2 lb., and of hydrogen equal to 7 1-2 lb.: it frequently happens that the cokes contain a larger portion of water than is here stated. When cokes thus surcharged are introduced in quantity into the blast-furnace, the quality of the metal is not always instantaneously changed, and frequently the colour and form of the cinder remain long without any great alteration. The contact of wetted cokes with the ore is first seen by the great discharge of pale-blue gas, with the whiter flame at the top of the furnace; next, the accumulating oxyde upon the surface of the pig when consolidating indicates their presence. Iron thus oxygenated, frequently exhibits while fluid, that agitation and delicate partings peculiar to carbonated metal: the remelting of this iron is never attended with advantage, and is always unprofitable to the founder.

From the properties assigned to pit-coal in this and in former papers, the following facts may be deduced:—That charcoal is the basis of the manufacture of crude iron; that its proper application produces the most valuable qualities of pig-iron; that, by diminishing its relative

proportion, or contaminating its quality by heterogeneous mixtures, the value and fusibility of the metal is lost; but that, by a proper increase, and always in proportion to this increase will the fusibility and value of the iron be mended. From the whole, an important lesson may be learned of the pernicious effects of water in the furnace, and how absolutely necessary it is to prepare the cokes without using water, either to damp the fires, as in the usual mode, or to cool the cinders obtained from the tar kilns, to prevent their consuming in the open air: in all this hurtful operation, considerable quantities of water become fixed in the cokes, which require a very great degree of heat to expel.

The preparation of iron-stone has already been fully attended to, and the phenomena which it exhibits under every stage minutely described. In consequence of various experiments we are authorised to draw the following conclusions: That when pure calcareous iron-stone is used, it admits of having the local quantity of cokes diminished; that argillaceous requires a larger portion than the calcareous genus; and that siliceous iron-stone requires a greater proportion of fuel than any variety of the former genera. We have also seen that fusibility, either connected with strength or otherwise, is derived from the mixture of the ores; and that excessive brittleness, intimately connected with infusibility, is also derived from the same source. From a review of these facts, we are forcibly impressed with the importance of combining the prepared iron-stones with proportions of fuel suited to their various natures, in order to produce all the varieties of crude iron with the greatest possible œconomy. Contemplating farther the same subject, it is easy to be conceived that a want of knowledge of the component parts

of iron-stones, and the effects which individually they produce, must lead to great uncertainty of operation in the smelting process, wherein the beautiful œconomy of nature, and even real property, will be often unprofitably sacrificed to precedent.

Besides the above causes of alteration, dependent upon mixtures of the earths, the existence of oxygen in various quantities in the ores ought never to be overlooked in proportioning the cokes to the iron-stone. This powerful agent whose form and substance constantly eludes our vision; whose existence is only ascertained by the wonderful changes produced by its various combinations with the iron; and whose presence in the same iron-stone, in various quantities, may produce such variety of result as to characterise the ores, as containing *good* or *bad* iron, surely forms the most interesting mixture which ores or iron-stones possess. It will be a momentous epoch in the manufacture of iron when the existence of such a principle shall be fully admitted by the manufacturer, and its agency, from certain visible effects produced, adopted to explain its accompanying phenomena. Till that period he will not perceive the utility of ascertaining the quantity of oxygen, and devising œconomical methods of taking it from the ore. An attention to this powerful principle can alone root out those prejudices so inimical to the real interests of the manufacturer, and which seem to glance at Nature, as having improvidently combined her most useful metal with mixtures which could resist the ingenuity of man, or set his comprehensive intellect at defiance. In the progress of this great inquiry, is it not possible that the present expensive exertions may in part be superseded? Is it not possible, that, by laying open the sources of information to individuals at large, a greater mass of intellect may engage in the practice of this art? While the present extensive and lofty buildings are necessary, the business is

entirely confined in the hands of men of great capital: the extent of their manufactures require that a large tract of country be devoted to their supply; a natural consequence is, that innumerable small tracts of land are overlooked, or held unworthy of notice, merely because they cannot, in a period necessary to clear a great capital and insure a fortune, afford the necessary supply of materials. Such situations, according to the present state of the iron business, must remain unexplored. Should, however, a desire for truth once gain footing in the manufactories of iron, and should this natural impulse of the unprejudiced mind keep pace with other branches of intellectual information, we may not despair of seeing many imperfections removed, which were the unavoidable consequence of the period of their creation.

In the application of iron-stone in the blast-furnace, the following particulars ought rigorously to be attended to:

1. Their mixtures, whether clay, lime, or silex: their relative proportions to each other, judging according to the rules formerly laid down; which of them may admit of a diminution of fuel; which of them will afford the quality of iron at the time requisite; and which of them will be most likely, by a judicious arrangement, to give the greatest produce of metal, united with value and œconomy. Iron-stones, united with large portions of silex, have already been stated to require a greater proportion of fuel to carbonate their metal than the other genera. When ballast or forge-pigs are wanted, it stands to reason that siliceous iron-stones ought to be used; not that they contain a greater quantity of iron, but because they form a substitute for the other kinds, which may be more advantageously smelted for the production of more valuable qualities.

2. The quantity of metal which each individual iron-stone may contain, is another object of consideration.

Besides the proportion of mixtures, which chiefly contribute to the fusibility of iron-stones, a second degree of fusibility is dependent upon the richness of the ore in iron: this is so obvious in the use of the Cumberland and Lancashire ores, that the consequences of their introduction will be perceived, by the change of the scoria and metal, in half the time that change would be effected by ordinary iron-stones. It has been frequently noticed, that crude iron contained pure carbon in proportion to its fusibility; then the more fusible, or supercarbonated qualities, must take up, comparatively, a considerable portion of the carbonaceous principle from the fuel. From this results a striking consequence, that the quantity of fuel should, over and above its relation to the mixtures, bear a just proportion to the quantity of iron in the stone: for example, let the weight *per* charge of fuel at a blast-furnace be 400 lb., and let this be supposed sufficiently to fuse and carbonate the iron contained in 360 lb. of iron-stone; let the quantity of metal be supposed 35 *per cent.* then the produce will be 126 lb. Should a change take place, and iron-stone richer in iron be applied, though the same by weight, and should this iron-stone yield of torrefied stone 45 *per cent.* its produce will be 162 lb. or 40 lb. more than the former. As there exists no greater proportion of carbon in the furnace, it is evident that the existing quantity, being distributed over nearly 1-3d of more metal, must therefore be in more sparing quantity in the whole, and the value of the metal consequently reduced.

3. The weight of oxygen contained in iron-stones is the next object of serious consideration. I have already shewn, from experiment, that our iron-stones naturally contain from 9 to 14 *per cent.* of oxygen, which remains after torrefaction: it has also been shewn, that this quantity of hurtful mixture may easily be doubled by over-roasting or under-roasting the stone; and that the bad ef-

fects entailed are in the ratio of its combination with the iron. From a review of the facts adduced on this subject in various parts of my papers, its agency and effects will easily be credited by men of science; its property of constituting the acidifying base of all the acids readily explains the unalienable consequence of its presence with acidifiable bases. The effects are still more pernicious when the oxygen is furnished by the decomposition of water in raw iron-stone; the hydrogen in this case set free, also seizes a portion of the carbon; and these abstractions, united to that produced by the native portion of oxygen in the stone, form an aggregate which frequently reduces the value of iron 40 *per cent.* So long as the princiciples of science are overlooked in the manipulations of the foundry and forge, the existence of such agents will be treated as chimeras of the philosopher and chemist, and the effects hourly produced by them, industriously attributed to causes, which in point of unity or consistency, will not bear the slightest touch of investigation.

Of the Iron produced from the blast furnace. I have already touched upon this in the preceding paragraphs, but the subject is worth pursuing.

" The great object of the manufacturer is, with a given quantity of fuel to obtain as large an amount as possible of highly carburetted cast iron, as this is the kind which bears the highest price in the market: but as from various causes the iron is generally found to be more or less decarburetted, it becomes a matter of considerable importance to ascertain by external characters the principal changes induced by a progressive diminution of carbon, in order that the value of any particular sample may be correctly and expeditiously ascertained. By long and careful observation, it has been found sufficient for all practical

purposes to arrange the several kinds of cast iron under one or other of the four following subspecies.

1. *Smooth faced Iron*, or *No.* 1. of the manufacturers. This seems to be composed of iron supersaturated with carbon, and mixed with a comparatively small proportion of oxyd and earthy impurities. Its upper surface is smooth and convex, entirely free from oxyd, and often covered with a thin crust of plumbago: it presents a coarse granular fracture with a brilliant metallic lustre and a dark blue colour.

2. *Good melting pig Iron*, or *No.* 2. of the manufacturers. This differs from the preceding in containing probably a smaller portion of carbon and a larger admixture of oxyd of iron. Its upper surface is slightly convex and full of small cavities: its fracture is coarse granular towards the centre of the pig, but the concretions manifestly diminish in size as they are situated nearer the surface; its colour is dark grey inclining to blue.

3. *Grey Iron*, or *No.* 3. of the manufacturers. In this the amount of carbon is still further diminished. Its upper surface is level, sometimes slightly concave, and presents more and larger cavities than the preceding, it is slightly oxydated superficially; its fracture is fine granular, and its colour is light grey.

4. *White Iron*, *forge pigs*, *ballast Iron*. In this the quantity of combined carbon is smaller and the admixed oxyd larger than in any of the preceding. Its upper surface is concave, rough, and covered with a plate of oxyd; its fracture is compact sometimes tending to striated, its colour is tin-white, occasionally mottled with grey.

We shall now proceed to state in a general way, the circumstances in the smelting which principally influence the quality of the produce. Much depends on the fuel: if the cokes are not perfectly made but retain a part of their bitumen, the whole mass cakes together in the upper

part of the furnace, and instead of descending regularly to the focus of heat, falls down by pieces, and at irregular intervals, so that part of the metal is detained too long before the blast, and in consequence is decarbonized and oxydated, while other portions pass so rapidly through the furnace as never to be thoroughly reduced, hence the amount of the produce is diminished and its quality greatly deteriorated. Nor is it of less importance that the coke should be perfectly dry when put into the furnace, otherwise the water which it contains will be decomposed, the hydrogen and part of the oxygen will dissolve their respective portions of carbon, and escape in a gaseous state, while the remainder of the oxygen will combine with the iron; which will thus be injured, not merely by the privation of carbon, but the positive addition of oxygen. It is further requisite that the proportion of fuel be adapted to the richness of the ore, so that there may be sufficient both to keep up the necessary degree of heat as well as to carbonize the metal: hence as the charges of ore and fuel are always proportioned by measure, if an ore somewhat richer than usual happens accidentally to be employed without a corresponding addition of fuel, the produce, though somewhat increased in quantity, will be more than equivalently reduced in quality. Another circumstance that the manufacturer must carefully attend to, is the proper choice of ore with regard to fusibility, for as it is not only requisite that the iron should be melted, but also highly carbonized, and as coke gives off its carbon with much more difficulty than charcoal does, it is manifest that a very fusible ore would melt long before it arrived at the focus of the furnace, and passing rapidly through, would reach the hearth without having had time to imbibe the proper quantity of carbon. Hence it is that the rich hæmatites, although they afford an excellent quality of iron when smelted with charcoal, produce nothing but white

iron when treated in the coke furnace; while on the other hand argillaceous iron-stone being much more refractory, does not melt till it comes into the very hottest part of the furnace, and therefore has had full time to absorb the desirable quantity of carbon. Another thing to be attended to is the proper regulation of the blast, and this depends upon its dryness, its temperature, its compression, and its direction. The dryness and temperature appear to be principally governed by the season of the year, and therefore are but little capable of being modified by the manufacturer. It is plain that the dryer and colder the air is, the greater will be its effect on the combustion, and it is found by constant experience, that the produce of iron during the summer months is greatly inferior in quantity, and materially so in quality to that which is manufactured in the winter: a clear, dry and severe frost is the most favorable period in every respect for the working of the furnace, and a change to snow or rain is infallibly followed by a corresponding deterioration. The higher the temperature of the blast is when it is delivered into the furnace, the smaller (the degree of compression and other circumstances being equal) will be the quantity of oxygen contained in every cubic foot, and of course the vigour of the combustion. Nor is the force of the blast and its direction a subject of less importance; it is obvious that in proportion as the charge descends, the carbonaceous matter is continually diminishing, hence the proper situation for the focus of the blast is that part of the furnace, where, when the ore shall have arrived, it will be fully carbonized and surrounded with a sufficient quantity of fuel to excite an intense heat, and absorb nearly the whole of the oxygen of the air, and thus prevent it from either oxydating the iron, or carrying off the carbon with which it may be combined. This precise situation, in a furnace properly constructed, will be found to be just within the expansion of

the boshes; but as this is more than four feet above the tuyere hole, the blast must be delivered with great velocity, and in a direction somewhat slanting upwards, in order that it may be reflected by the opposite wall of the crucible, and arrive at its proper place without undergoing any material decomposition. When the blast enters too rapidly, and in too concentrated a state, it renders the line of its passage before it is reflected so cool, that the descending slag which comes within its influence is suddenly solidified, and blown into a tube reaching perhaps half way across the crucible through which the blast continues to rush, and in consequence of this protection, is conveyed with greater precision, and in a less decomposed state into the upper part of the furnace. If after this, the compression of the air is somewhat diminished, the tube still remains firm, often for days together, and the furnace works in the best manner. But on the other hand, when too loose and soft a blast is admitted, and more especially if it be charged with moisture, it is unable to reach the top of the crucible without being decomposed, and the reflection which it undergoes from the wall of the crucible, weakens and disperses it to such degree, that the combustion which ought to take place within the boshes, now occupies the whole upper part of the crucible: in consequence of this, the tube of scoriæ is presently burnt away, the iron almost as fast as it is melted is ignited and oxydized, the tuyere hole glows like the sun, with an intensely vivid white light; the scoriæ from being yellowish white, streaked with blue, becomes green, brown, and finally black, nearly the whole of the iron in the state of oxyd being taken up by it; the blocks of refractory gritstone with which the lower part of the furnace is lined are worn into great holes, and in the space of a few hours prodigious damage is sustained.

The following further remarks on this head are by Mr. Mushet—5 *Phil. Mag*. 128.

When fine (No. 1.) or supercarbonated crude iron is run from the furnace, the stream of metal, as it issues from the fauld, throws off an infinite number of brilliant sparkles of carbon. The surface is covered with a fluid pellicle of carburet of iron, which, as it flows, rears itself up in the most delicate folds; at first the fluid metal appears like a dense, ponderous stream, but, as the collateral moulds become filled, it exhibits a general rapid motion from the surface of the pigs to the centre of many points; millions of the finest undulations move upon each mould, displaying the greatest nicety and rapidity of movement, conjoined with an uncommonly beautiful variegation of colour, which language is inadequate justly to describe. Such metal, in quantity, will remain fluid for twenty minutes after it is run from the furnace, and when cold will have its surface covered with the beautiful carburet of iron, already mentioned, of an uncommonly rich and brilliant appearance. When the surface of the metal is not carburetted, it is smooth like forged iron, and always convex. In this state, iron is too rich for melting without the addition of coarse metal, and is unfit to be used in a cupola furnace for making fine castings, where thinness and a good skin are requisite.

No. 4, or oxygenated crude iron, when issuing from the blast-furnace, throws off from all parts of the fluid surface a vast number of metallic sparks: they arise from a different cause than that exerted in the former instance. The extreme privation of carbon renders the metal subject to the combination of oxygen so soon as it comes into contact with atmospheric air. This truth is evidently manifested by the ejection of small spherules of iron from all parts of the surface: the deflagration does not, however, take place till the globule has been thrown

two or three feet up in the air; it then inflames and separates, with a slight hissing explosion, into a great many minute particles of brilliant fire. When these are collected they prove to be a true oxyd of iron, but so much saturated with oxygen as to possess no magnetic obedience. The surface of oxygenated iron, when running, is covered with waving flakes of an obscure smoky flame, accompanied with a hissing noise; forming a wonderful contrast with the fine rich covering of plumbago in the other state of the metal, occasionally parting and exhibiting the iron in a state of the greatest apparent purity, agitated in numberless minute fibres, from the abundance of the carbon united with the metal.

When iron thus highly oxygenated comes to rest, small specks of oxyd begin to appear floating upon the surface: these increase in size; and when the metal has become solid, the upper surface is found entirely covered with a scale of blue oxyd of various thicknesses, dependent upon the stage of oxygenation or extreme privation of carbon. This oxyd, in common, contains about 15 *per cent.* of oxygen, and is very obedient to the magnet. In place of a dark blue smooth surface, convex and richly carbonated, the metal will exhibit a deep rough concave face, which, when the oxyd is removed, presents a great number of deep pits. This iron in fusion stands less convex than carbonated iron, merely because it is less susceptible of a state of extreme division; and indeed it seems a principle in all metallic fluids, that they are convex in proportion to the quantity of carbon with which they are saturated. This iron flows dead and ponderous, and rarely parts in shades, but at the distance of some inches from each other.

This is a slight sketch of the appearance of the two extreme qualities of crude, or pig-iron, when in a state of fusion. According to the division formerly made, there still

remains two intermediate stages of quality to be described: these are, carbonated and carbo-oxygenated iron; that is, No. 2 and 3 of the manufacturers. Carbonated iron exhibits, like No. 1, a beautiful appearance in the runner and pig. The breakings of the fluid, in general, are less fine; the agitation less delicate; though the division of the fluid is equal, if not beyond that of the other. When the internal ebullition of the metal is greatest, the undulating shades are smallest and most numerous: sometimes they assume the shape of small segments; sometimes fibrated groups; and at other times minute circles, of a mellower colour than the ground of the fluid. The surface of this metal, exposed to external air, when cooling is generally slightly convex, and full of punctures: these, in iron of a weak and fusible nature, are commonly small in the diameter, and of no great depth. In strong metal, the punctures are much wider and deeper. This criterion, however, is not infallible, when pig-iron of different works is taken collectively. At each individual work, however, that iron will be strongest whose honeycombs are largest and deepest.

Carbo-oxygenated, or No. 3, pig iron, runs smoothly, without any great degree of ebullition or disengagement of metallic sparks. The partings upon its surface are longer, and at greater distances from each other than in the former varieties; the shape they assume is either eliptical, circular, or curved. In cooling, this metal acquires a considerable portion of oxyd; the surface is neither markedly convex nor concave; the punctures are less, and frequently vanish altogether. Their absence, however, is no token of a smooth face succeeding; in qualities of crude iron oxygenated beyond this, I have already mentioned that a concave surface is the consequence of the extreme absence of carbon; and that, in proportion as this princi-

ple is absent, the surface of the iron acquires roughness and asperity.

It may perhaps be proper here to mention, once for all, that although, for convenience, the manufacturer has, from a just estimation of the value of the metal in a subsequent manufacture, affixed certain numbers for determinate qualities of iron, yet it is difficult to say at what degree of saturation of carbon each respective term commences: suffice it then to say, that the two alterative principles, oxygen and carbon, form two distinct classes, that in which oxygen predominates—and that in which carbon predominates; the latter comprehends No. 1 and 2 of the manufacturers, the former includes oxygenated, white and mottled; and the equalization of these mixtures form, as has already been noticed, the variety of carbo-oxygenated crude iron.

I shall now observe some things relative to the various faces which crude iron assumes. No. 1 and 2, with their intermediate qualities, possess surfaces more or less convex, and frequently with thin blisters: this we attribute to the presence of carbon, which being plentifully interspersed betwixt and throughout the particles of the metal, the tendency which the iron has to shrink in cooling is entirely done away; it tends to distend the aggregate of the mass, and to give a round face, by gradually elevating the central parts of the surface, which are always last to lose their fluidity.

Again, that quality of iron known by the name of No. 3, or carbo-oxygenated, or with about half its full dose of carbon, is most commonly found with a flat surface. If we still farther trace the appearance of the surface of pig iron, when run from the furnace, we shall find No. 4 either with a white or mottled fracture, possessed of concave faces, rough and deeply pitted. Beyond this it may be imagined that every degree of further oxygenation would be

productive of a surface deeper in the curve, and rougher, with additional asperities. The contrary is the case: when crude iron is so far debased as to be run from the furnace in clotted lumps highly oxygenated, the surface of the pigs is found to be more convex than that of No. 1. iron; but then the fracture of such metal presents an impure mass covered on both faces with a mixture of oxydated iron, of a blueish colour, nearly metallic. In short, this quality of iron is incapable of receiving such a degree of fluidity as to enable us to judge whether the convexity of its surface is peculiar to its state, or is owing to its want of division as a fluid, whereby the gradual consolidation of the metal is prevented.

These features sufficiently distinguish betwixt the various qualities of crude iron after they are obtained from the blast-furnace: there are, however, criterias not less infallible, whereby we can prejudge the quality of the metal many hours before it is run from the furnace. These are the colour and form of the scoria, the colour of the vitrid crust upon the working bars, and the quantity of carburet which is attached to it. The variety of colour and form in the cinder almost universally indicate the quality of the metal on the hearth. Hence, from a long course of experience, have arisen the following denominations: "Cinder of sulphury iron;" "Cinder of No. 1, No. 2, and No. 3;" and "Cinder of ballast iron." Although at different works, from local circumstances, the same kind of scoria may not indicate precisely the same quality of iron, yet the difference is so small that the following description of the various cinders may convey a very just idea of their general appearance.

When the scoria is of a whitish colour and short form, branching from the notch of the dam, and emitting from its stream beautiful sparks of ignited carbon, resembling those ejected from a crucible of cast steel in fusion, ex-

posed to external air, or to the combustion of fine steel filings in a white flame; if, when issuing from the orifice of the furnace, it is of the purest white colour, possessing no tenacity, but in a state of the greatest fluid division, and, when cold, resembles a mass of heavy torrefied spar, void of the smallest vitrid appearance, hard and durable, it is then certain that the furnace contains *sulphury iron*, i. e. super-carbonated iron. At blast-furnaces, where a great quantity of air is thrown in per minute, super-carbonated crude iron will be obtained with a cinder of a longer form, with a rough flinty fracture towards the outside of the column.

That cinder which indicates the presence of carbonated iron in the hearth of the furnace, forms itself into circular compact streams, which become consolidated and inserted into each other; these are in length from three to nine feet. Their colour, when the iron approaches the first quality, is a beautiful variegation of white and blue enamel, forming a wild profusion of the elements of every known figure; the blues are lighter or darker according to the quantity of the metal and the action of the external air while cooling. When the quality of the pig-iron is sparingly carbonated, the blue colour is less vivid, less delicate; and the external surface rougher, and more sullied with a mixture of colour. The same scoria, when fused in vessels which are allowed to cool gradually, parts with all its variety of light and shade, and becomes of a yellowish colour, sometimes nearly white when the quantity of incorporated metal has been small.

The cinder which is emitted from the blast-furnace when carbo-oxygenated (or No. 3,) iron is produced, assumes a long zig-zag form. The stream is slightly convex in the middle; broad, flat, and obliquely furrowed towards the edges. The end of the stream frequently rears itself into narrow tapered cones, to the height of six

or eight inches: these are generally hollow in the centre, and are easily demolished, owing to their excessive brittleness. The colour of this lava is very various; for the most part it is pale yellow mixed with green. Its tenacity is so great, that if, while fluid, a small iron hook is inserted into it at a certain degree of heat, and then drawn from it with a quick but steady motion, 20 to 30 yards of fine glass thread may be formed with ease. If the colours are vivid and variegated, the thread will possess, upon a minute scale, all the various tints of colouring which is found in the columnar mass. When by accident a quantity of this lava runs back upon the discharging-pipe, it is upon the return of the blast impelled with such velocity as to be blown into minute delicate fibres, smaller than the most ductile wire; at first they float upon the air like wool, and when at rest very much resemble that substance.

The presence of oxygenated crude iron (No. 4,) on the furnace-hearth, is indicated by the lava resolving itself into long streams, sometimes branched, sometimes columnar, extending from the notch to the lowest part of the declivity; here it commonly forms large, flat, hollow cakes, or inclines to form conical figures: these are, however, seldom perfect; for the quantity of fluid lava, conveyed through the centre of the column, accumulates faster than the external sides of the cone are consolidated; and thus, when the structure is only half finished, the small crater vomits forth its superabundant lava, and is demolished. The current of such lava falls heavily from the dam as if surcharged with metal, and emits dark red sparks resembling the agitation of straw embers. Its colour is still more varied than the former descriptions of scoriæ, and is found changing its hues through a great variety of greens shaded with browns. Another variety of scoria, which indicates the same quality of iron, as-

sumes a similar form; but has a black ground colour mixed with browns, or is entirely black. When the latter colour prevails, the texture of the cinder becomes porous; the quantity of iron left, is now very considerable, and such as will be easily extracted in the assay-furnace, with proper fluxes. In cases of total derangement in the furnace, the scoria will still retain this black colour, although the quantity of metal may amount to 25 *per cent:* the fracture, however, becomes dense, and its specific gravity increases in proportion to the quantity of metal it holds incorporated.

The next source of information, as to the quality of the iron in the furnace, is to be got from the colour of the scoria upon the working bars, which are from time to time inserted to keep the furnace free from lumps, and to bring forward the scoria. When super-carbonated crude iron is in the hearth, the vitrid crust upon the bars will be of a black colour and smooth surface, fully covered with large plates and brilliant of plumbago.

As the quality of the metal approaches to No. 2. (carbonated) the carburet upon the scoria decreases both in point of quantity and size.

When carbo-oxygenated iron (No. 3.) is in the furnace, the working bars are always coated with a lighter coloured scoria than when the former varieties exist; a speck of plumbago is now only found here and there, and that of the smallest size. When the quality of the metal is oxygenated (No. 4.) not only have the plates of carburet disappeared, but also the coally colour on the external surface of the scoria; what now attaches to the bars, is nearly of the same nature and colour as the lava emitted at the notch of the dam.

These criteria are infallible; for, as the fusibility or carbonation of the metal is promoted in a direct ratio to the comparative quantity of the coally principle present

in the furnace, so in the same proportion will the vitrid crust encircling the working bars exhibit the presence of that principle in the furnace."

"The highly carburetted, kishy, *smooth faced*, very fusible iron, No. 1, bears the best price, as it is used for all the finer castings, and for cast iron cutting, as forks, scissors, &c.

The iron called *melting iron*, No. 2, is also super-carbonated, or carburetted, but in a less degree; this is used for wheels, beams, pillars, railways, &c.

The *forge pig* is used exclusively for malleable iron.

The following account may serve to throw some light on the faults and defects of iron and therefore I have abridged it from the 8th Sect. of Bergman (or Gadolin's thesis) *de Analysi Ferri.*

Peregrina ferro inhærentia. Of the foreign substances contained in iron.

These are, manganese, arsenic, zinc, plumbago, and sulphuric acid. He might have added, nickel, siderite or phosphat of iron, and copper.

If the ore be fused with 5 times its weight of nitre, the manganese if any, will be discovered by the blue tinge of the fused slag: when iron is also dissolved in the scoria, the glass will be of a bluish green; but I do not know that manganese is any detriment either to iron or steel. Its properties were first detected by Bergman in his dissertation on the white ores of iron. No coal should be permitted to enter the crucible in this experiment. From Bergman's Experiments, most of the Swedish crude iron appears to contain manganese. This substance may also be detected by boiling iron in strong clear vinegar; then add a solution of pearl ash. If there be a *white* precipitate, it is manganese: one part of the dried precipitate, denotes 1-2 a part of metallic manganese. We are sadly in want of a series of experiments to ascertain the effect

of various proportions of manganese and iron fused together. But the opinions of an experienced iron master and a good blacksmith, should be taken upon the specimens produced.

Arsenic, is best detected by roasting the pulverized ore; but Bergman could detect none in the cold-short iron of Grœnge: but he says that its presence, deprives iron of its magnetism, and renders it both red-short, and cold-short. Muriatic acid will take up the iron and leave the arsenic. Aqua regia will take up both, but water will throw down the arsenic.

Zinc is sometimes found in iron, but seldom. The cold-short property is not attributable to this metal. The blue colour of the bright flame, and the white sublimate discover it. But it is not found in cold-short iron.

With respect to plumbago, Bergman was not aware, that a superabundant quantity of charcoal would form it: nor did he then know, I believe, that black lead or plumbago was a very carburetted iron, in which the iron was in small proportion.

With respect to the acid of vitriol, modern knowledge will acquit it of forming any component part of iron, or of being instrumental in any of its faults.

It is singular that in Bergman's Experiments, cold-short iron dissolved in acids, and precipitated by the prussiat of potash into Prussian blue, continued cold-short on being again reduced into metallic iron.

Bergman also attributed the quality of cold-short iron to siderite or phosphat of iron; but I agree with Mr. Mushet that the violent heats of a furnace and refining, are sufficient to decompose this substance.

Nickel has been found in iron, but I know not of any bad effect from it. Nickel precipitated with iron, and the latter reduced to a red or peroxide by hyper-oxymuriate of lime, the nickel may be separated by pure ammonia.

Iron ores frequently contain copper, and if it be in a proportion more than about 12 *per cent.* the iron is manifestly the worse for it. The combination of good copper with good iron does not make it better; and the process of manufacturing malleable iron from the ore, is not sufficient to produce good copper. Where the copper is in large proportion, I know not as yet any method of separating it profitably. Such methods are noticed by Jars and Schlutter, but they are not sufficiently detailed to be relied on.

With respect to the qualities of cold and red short iron, I cannot find any information on which my readers can rely as to the cause. Whether it be owing to an overdose of carbon, to siderite, to arsenic, to manganese, to copper, is not yet settled. The cure can only be found in the refinery furnace, and the tilt hammer, or the rollers.

Of the Refinery or Bloomery, and the conversion of crude iron into malleable iron.

There has been no regular analysis of cast iron, but from the phenomena that take place during its conversion into bar iron, which we shall proceed to describe, it will be sufficiently apparent what are its principal constituent parts.

One of the most obvious differences between cast and bar iron, is the brittleness of the former and the malleability of the latter: this malleability has accordingly been adopted by the manufacturer as the essential character of bar iron, and as affording him a mode by which to judge of the efficacy of the means employed by him in reducing crude to malleable iron.

The first step in the process is refining*. For this purpose the pigs are smelted in a refinery, (the construction of which we have already noticed) by means of char-

* Collier in Manchester, Trans.

coal; and as soon as the metal is in fusion it is let out into a mould of sand to separate the scoria that rise to its surface, and in this state is called a *half bloom.* As soon as it has become solid it is again transferred to the furnace and treated as before. Sometimes even a third fusion is required before the iron shews sufficient malleability to clot into lumps when broken down almost at a fusing heat, by an iron bar. When it has acquired this consistency, it is taken out in moderate size pieces, which being placed under the great forge or *shingling* hammer, are speedily stamped into cakes about an inch in thickness. Several piles of these cakes about a foot high, are then laid on flat circular stones, and placed in the *balling* or reverberatory furnace, where they are strongly heated. As soon as the whole acquires a pasty state, one of the piles is taken out by a workman and drawn under the hammer into a short bar: which being finished, is applied to another of the piles, to which it presently adheres: being then withdrawn, the new portion is welded firmly to the first by means of the hammer, and thus the bar is doubled in length; by repeating the same simple and ingenious operation, the bar is made as long as its weight will conveniently allow. The cracks in the bar are then closed, and its tenacity is improved by heating it afresh in a fire made of coal, called the *chaffery*, (chaufferie Fr.) and again subjecting it to the action of the forge-hammer. It is now in the state of common bar iron, and ought to be entirely free from all earthy particles. After this, according to the use for which it is intended, it is transferred to the slitting mill; where it is laminated and cut up into bars and rods of various dimensions, by which its toughness and compactness is much improved, and is then ready for the smith.

The above method is called *stamping;* but besides this, there is another known by the name of *flourishing,*

which requires a short notice. In this the pigs of cast iron when put into the refinery, are kept for about two hours and a half in a pasty state without actually melting, and at the end of this period the metal is taken out by shovels and laid on the open floor on a plate of cast iron, where it is beaten with hand-hammers in order to knock off the cinders and other adhering impurities. It is afterwards placed under the forge hammer and beaten, at first gently, till the whole mass has acquired some tenacity, and then the middle part is drawn into a bar four feet long, terminated at each extremity by a cubical lump of rough iron: in this state it is called an *Ancony*. It is now taken to the Chaffery, hammered afresh, and the ends being also drawn down to the same dimensions as the other part, the bar is compleated.

A third method of working iron, called *puddling*, was invented by Mr. Cort, (as appears from the specifications of his two patents*) and is we understand coming into general use at Sheffield and other places. It is particularly characterised by combining the reverberatory with the finery furnace, and the whole process is managed in the following manner. The pigs of cast iron produced by the smelting furnace are broken into pieces, and are mixed in such proportions according to their degree of carbonization, that the result of the whole shall be a grey metal. This mixture is then speedily run down in a blast furnace, where it remains a sufficient time to allow the greater part of the scoriæ to rise to the surface. The furnace is now tapped, and the metal runs into moulds of sand, by which it is formed into pigs about half the size of those which are made at the smelting furnace; and these pigs when cold are broken into pieces.

* See Repertory of Arts, III. p. 289 and 361, (old series,) for Mr. Cort's two patents.

A common reverberatory furnace heated by coal, is now charged with about $2\frac{1}{2}$ cwt. of this half refined grey iron. In a little more than half an hour, the metal will be found to be nearly melted; at this period the flame is turned off, a little water is sprinkled over it, and a workman by introducing an iron bar, or an instrument shaped like a hoe, through a hole in the side of the furnace, begins to stir the half fluid mass and divide it into small pieces. In the course of about fifty minutes from the commencement of the process, the iron will have been reduced by constant stirring to the consistence of small gravel, and will be considerably cooled. The flame is then turned on again, the workman continuing to stir the metal, and in three minutes time the whole mass becomes soft and semifluid, upon which the flame is again turned off. The hottest part of the iron now begins to heave and swell, and emit a deep-blue lambent flame, which appearance is called fermentation: the heaving motion and accompanying flame soon spreads over the whole, and the heat of the metal seems to be rather increased than diminished for the next quarter of an hour; after this period the temperature again falls, the blue flame is less vigorous, and in a little more than a quarter of an hour the metal is cooled to a dull red, and the jets of flame are rare and faint. During the whole of the fermentation, the stirring is continued, by which the iron is at length brought to the consistency of sand, it also approaches nearer to the malleable state, and in consequence adheres less than at first to the tool with which it is stirred. During the next half hour the flame is turned off and on several times, a stronger fermentation takes place, and a loud hissing noise is perceived, the lambent flame also becomes of a clearer and lighter blue; the metal begins to clot and becomes much less fusible and more tenacious than at first; the fermentation then by degrees subsides, the emission of blue flame nearly ceases, the iron

is gathered into lumps and beaten with a heavy-headed tool. Finally, the tools are withdrawn, the apertures through which they were worked are closed, and the flame is turned on in full force for six or eight minutes. The pieces being thus brought to a high welding heat are withdrawn and shingled; after this they are again heated and passed through grooved rollers, by which the scoriæ are separated and the bars thus forcibly compressed acquire a high degree of tenacity.

The more welding and hammering that bar iron is subject to, the tougher it becomes and the more fibrous, or nervous as the French term it, is the fracture. Hence arises the superiority of *Stub iron* to all the other varieties for barrels of fowling pieces and other uses where extreme toughness is required. It is prepared in the following method. A moderately broad ring of the best Swedish iron is placed horizontally and filled with old horseshoe nails (called stubs) set perpendicularly, till it can hold no more: a pointed bar of iron is then driven into the centre of the circle, and thus locks the whole fast together. A welding heat is then applied, and the mass is hammeredvery gently at first, till the nails and ring become compleatly united: it is then drawn down into bars and affords an iron of peculiar closeness, toughness, and malleability."—*Aikin.*

"To produce malleable iron in its pure state, many and various have been the processes adopted: these however have all in some measure fallen short. Malleable iron ought to possess no foreign mixture whatever, to be in a state of purity; but as the modes of operation have hitherto consisted in manufacturing this state of the metal from crude iron, and as crude iron is always found to contain principles inimical to malleability, it is obvious, that the quality of malleable iron will at all times depend upon the degree of expulsion of the alterative mixtures contain-

ed in the crude iron, the destruction of which, and the consequent malleabilization of the iron, constitute the universal acknowledged principles of bar-iron making.

From the imperfect dissipation of oxygen, and carbon in the process of giving malleability, arise the various qualities of malleable iron; these may be arranged in the following order:—1. Hot-short iron;—2. Cold-short iron;—and, 3. Iron partaking of none of these evils; and so far it may be denominated pure malleable iron.

1. Hot-short iron is possessed of an extreme degree of fusibility when in contact with a high degree of heat, and is incapable of receiving the weight of a small hammer without dissipating; it is, however, possessed of an extreme degree of softness and ductility when cold, and may then be bent or twisted in almost any direction. Various reasons have been assigned for this destructive property in hot-short iron. I am of opinion, that it arises from the iron containing a small portion of concrete carbon, not extirpated during the operation of rendering the iron malleable; and that in proportion to the quantity of carbon united, so will be the shortness or fusibility of the iron: this variety of iron is always of a dark coloured unmetallic fracture.

2d. Cold-short iron is possessed of the property of withstanding the most violent degree of heat, without exhibiting the least indication to fusion; it remains firm under the heaviest hammer, and is capable, while hot, of being beat into any shape: when cold, however, it is brittle, and possessed of a small degree of tenacity: its fracture is always clear and large-grained, of a light blueish colour. A small portion of iron dissolved in the phosphoric acid is now believed to constitute the cold-short principle of iron. Besides the difficulty of conceiving how an acid could exist in the violent and long continued heats of the refinery, the puddling and balling furnaces, wherein the metal

is subjected to motion, frequently agitated, and extremely divided, how does it happen, that that iron on which the cold-short principle is impressed, becomes more and more cold-short, by a continued exposure to the combination of oxygen with caloric, either excited by blast or the attenuated heat of a wind furnace? This fact would imply a generation of the alterative principle—which is indeed the case—but which cannot be admitted, if the cold-short quality is attributed to the phosphat of iron; unless recourse is had to the supposition of a new combination of this metallic salt during the operation.

If highly oxygenated crude iron, of any manufacture, is exposed to the action of a current of flame, after its small portion of carbon is burnt out, and after the mass has exhibited the proper signs of malleability, it will pass into the state of cold-short iron; and this principle will exist in proportion to the length of the exposure; or, in other words, in proportion to the oxygen presented to the metal, and its tendency to quit the caloric to unite with the iron.

3d. Pure malleable iron derives its strength, tenacity, malleability, and ductility, by being totally deprived of the principles which constitute the cold and hot-short qualities of iron. This is effected in the course of rendering it malleable, either by the attention of the workmen, or from the proper quality of the crude iron used: its fracture is generally clear, consisting of small regular dark blue grains; by much hammering the iron commonly gains fibre, and is then of a light blue colour, uncommonly tenacious when cold. The excellence of pure malleable iron is also manifested by the astonishing degree of heat it withstands without exhibiting the least sign of fusion, or without losing much of its metallic parts by oxydation.

A line of distinction ought to be drawn betwixt the iron produced with wood-charcoal and pit-coal. As the pre-

sent relation of the simple principles of the metal does not immediately interfere with that distinction, it will more properly arrange itself along with the observations on the various modes practised for rendering iron malleable.

However variously conducted the modes of operation are at different works, and in different countries, to produce malleable iron, yet the principle of operation is the same, namely, that by dissipating the carbon and oxygen, contained in the crude iron, bar or malleable iron is the result.

Furnaces of a multiplicity of shapes have been erected for this purpose; but in the most perfect conducted processes hitherto, it has been found, that a heavy loss of metallic parts accompanied the manufacture: 40, 35, to 30 cwt. of crude iron have been used to fabricate 1 ton of finished bars; the quantity used always depending upon its aptness to become malleable, the skillfulness of the workmen, the operation adopted, andthe quality of the malleable iron wished to be produced. These observations more immediately relate to the home manufactures of iron with pit-coal; but in many instanc es they will also apply to those of other countries, where the charcoal of wood is used for fuel.

Since crude iron exists of such a variety of quantities, owing to the various proportions of mixture united with it; and since it is almost universally used to produce bar or malleable iron; it is natural to infer, that there must exist one particular variety of it, which could be appropriated to the manufacture in preference to any other. Theory says that that crude iron, carbo-oxygenated, which contains the alterative principles in equal portions, requires only to be exposed in a fluid state to the action of fire, either in a wind furnace or small blast, By this exposure the carbon becomes volatilized in combination with the oxygen. Practice has however confined the opera-

tion chiefly to the forge pig (oxygenated crude iron). This variety of iron becomes sooner malleable, but is likewise susceptible of early oxydation, and consequently liable to become cold short. Neither can it unite to bar iron those properties from whence are derived great strength and ductility.

When carbonated crude iron is used, the waste then is apt to be excessive: the metal retains for too long a period its fusible principle, which must necessarily expose the mass to a longer continued action of the flame, whereby oxydation on the metal in a fluid state takes place, and a considerable portion of it is destroyed before the iron exhibit signs of infusibility. Malleable iron made from this state of the metal has a great tendency to be red short, and loses also considerably of its weight under the forge hammer.

It has at all times been asserted, that crude iron contains a considerable proportion of its parts, by weight, inimical to malleability; and that, in the operation of refining, it then parts with this proportion of mixture which renders the remainder malleable. A conclusive inference from this would be, that some crude irons contain one half, some three fourths, and others again an equal portion of mixture for iron; seeing these are the proportions lost by iron in the operation of rendering it malleable. The mischief with which this fallacious opinion is fraught is inconceivable; especially as it has been supported by men who have laid claim to scientific and practical abilities; the belief of it slackens the industry of individuals to attempt lessening the loss of real metal; on the contrary, workmen are taught to look upon a large proportion of it as incapable of being metallized, and as only fit for destruction.

If manufacturers of bar-iron would more frequently deprive a given weight of the scoria of the refinery and pud-

dling furnaces, of its iron, they would be more able to estimate the portion of unmetallic parts contained in their crude iron: upon finding the scoria to contain 30, 40, to 50 *per cent.* of iron, equally fit for converting into malleable iron as any part of the original mass, their attention would be more frequently arrested, and employed to devise means, either to prevent the escape of such a considerable proportion of iron, or to fuse such scoria so as to deprive it of the last portion of metal."—*Mushet.*

Conversion of Pig-iron into malleable Iron, and Steel. From Dr. Rees's Cyclopædia, new edition.

1. *Bar, or wrought Iron.* Iron, as obtained by the reduction of its ores in the blast-furnace, contains, as we have before stated, a certain proportion of carbon, which renders the metal unfit for the various purposes of forging, but constitutes its principal value as applicable to the use of the founder. To deprive it of this ingredient certain processes are gone through, the object of which is, by the concurrent action of heat and air, to dissipate the carbon under the form of an elastic compound. The kind of iron chosen for the conversion is that denominated by manufacturers *forge-pig.* It is the lowest quality made for the purposes of art; and, in consequence of its being combined with a smaller dose of carbon than any other, which thus causes it to bear a less price in the market, is doubly preferable for the end required.

The price of *pig-iron* is almost exclusively determined by the quantity of carbon which is in combination with it. The varieties usually distinguished are No 1, otherwise called *grey*, *smooth-faced*, or *kishy*, metal; Nos 2 and 3, and *forge-pig.* The proportion of carbonaceous matter present in these varieties is differently stated by different experimentalists. Clouet makes the highest proportion to amount to $\frac{1}{4}$th; but from the results obtained

by Mr. Mushet in combining iron *directly* with the doses of charcoal requisite to produce its various sub-carburets, $\frac{1}{15}$th appeared to be the *maximum*. Of this, the following table, published by him in the 13th vol. of the Philosophical Magazine, will afford the necessary proof.

Soft cast steel - - - - - -	$\frac{1}{120}$
Common ditto - - - - - -	$\frac{1}{100}$
Same, but harder - - - - -	$\frac{1}{90}$
Ditto, too hard for drawing - - - -	$\frac{1}{50}$
White cast iron, (same as before called *forge-pig*)	$\frac{1}{25}$
Mottled cast iron (No. 2.) - - - -	$\frac{1}{20}$
Black cast iron (No. 1.) - - - -	$\frac{1}{15}$

The first step in the process of decarbonization, according to the more common mode of operating, is to expose the iron in a furnace, called by some a *refinery*, but by others, to distinguish it from one hereafter to be described, a *run-out furnace*. It consists of a vessel open at the top, imbedded in stone or brick work, about two feet three inches long, two feet wide, and ten inches deep. This is generally, in part, constructed of cast iron; and, when so made, has an outer case about two or three inches distant from the inner one, which is constantly supplied with a stream of cold water to prevent the apparatus from melting. The iron to be decarbonized is placed in this receptacle, and kept in a continual state of fusion for three or four hours by the aid of a coke fire, which is heaped to a considerable height above the level of the vessel, and extended proportionally on the hearth that surrounds it. The size of the hearth is mostly about three yards in length, and from two to three wide, and is completely covered by the funnel of the overhanging chimney. Bellows of considerable size are employed to carry on the process; and the current of air which issues from them is directed immediately on the surface of the iron by one or more *tuyeres*. These *tuyeres* are double, like the case, and con-

tinually cooled by the application of the same means.— When the decarbonization is compleated, the metal is let out at an opening in the side, which has been kept close during the operation by a *stopping* of sand. It flows into a groove about 18 inches wide, and six or seven feet long, constructed of stone in the floor that surrounds the furnace. The bottom of the vessel is so placed as to be nearly on a level with the floor; the only elevation given to it being what is merely sufficient to let the iron run out with facility. A considerable quantity of vitreous oxyd is formed during the process; and the loss in the weight of metal, which is stated to amount to from $\frac{1}{6}$th to $\frac{1}{7}$th, is principally referable to this circumstance. The total quantity of carbon which the iron contains originally, is not estimated at more than $\frac{1}{27}$th; and yet the approach of it to the pure state, or, in technical language, to the state of *bar* or *wrought iron*, after this operation, is very inconsiderable.

The cake of metal procured by these means is broken into lumps of a convenient size, and subjected, in a furnace of another description, to a process known in the art by the name of *puddling*. The furnace, which is also distinguished by the same term, is a variety of the reverberatory; and at the immediate point where the flame strikes upon the hearth, a shallow concavity is worked out, in which the melted iron is exposed. Opposite to it is a door, and through this the metal is kept in continual agitation, by means of a sort of rake, for the purpose of exhibiting fresh surfaces perpetually to the influence of the air. Water is likewise occasionally thrown in, which in some degree contributes to the decarbonization. With the loss of carbon, the iron also loses its fusibility, and about the middle stage of the operation appears in the form of small detached lumps, which scarcely seem to exert any affinity for each other. At length, however, by

much stirring, and frequently pressing them together, they cohere into a pulpy mass; and being gathered into pieces of a convenient size, are carried under rollers, where, after passing through four pairs, in succession, of a gradually diminishing guage, they are produced into plates seven or eight inches wide, and three feet or more in length. Considerable quantities of matter are squeezed out in the rolling, which principally consist of a vitreous kind of oxyd. This is, for the most part, to be referred to the action carried on in the furnace: but some portion of it is, in all probability, created by the combustion of small pieces of fluid metal, which, engaged amongst the particles of the *puddled* mass, are hurled through the air in a state of vivid inflammation, by the compressive violence of the rollers. The total loss thus sustained is estimated at from 1-6th to 1-7th. The plates obtained by this treatment have a very incompact appearance: and if attempted to be worked in the state they are then presented under, would crumble almost wholly into small granulated lumps. To impart to them the necessary closeness and solidity, they are again heated in another kind of furnace, and beaten forcibly with a heavy hammer, which is raised by machinery.

Previously to being thus treated, they are broken up into cakes of small size, and placed upon circular slabs of stone from 8 to 12 inches in diameter. The size of the cakes is in a great measure determined by a particular effect of the last pair of rollers that they are passed through; ribs, of a diamond shape, girding either one or both of them, on the whole extent of their surface, which leave a deep indentation on the plates, so as to render them easily frangible in that direction. The height to which these cakes are piled on the circular slab just spoken of, is generally about 12 inches; and when so prepared, they are placed on the hearth of a reverberatory furnace, which

differs but little in form from that employed for *puddling*, except in being flat at the bottom instead of concave.— The furnace is denominated a *balling furnace;* and the piles of metal *pies* or *balls*. They are continued in this situation until they have arrived at a welding heat, and are then removed by large tongs under the stroke of the hammer. Near to the place a smith's forge is kept in blast, where long bars of iron aro also urged to the welding point; and after the first stroke or two of the hammer, united to the *balled* masses to afford greater convenience in turning them. The masses are beaten out into ingots of about three feet in length; and the bar last mentioned being separated, they are divided deeply by an instrument termed a *set*, to facilitate their being afterwards broken; and the process is then completed. They are in this state called *blooms*, and have yet to undergo another operation, for the purpose of being made into bars or plates. Much loss is sustained by the last treatment, and principally from the same formation of oxyd as was noticed in the preceding case. The quantity thus lost, added to the waste occasioned in the *bloomery*, which comes next to be described, is usually considered as equal to 1-5th of the metal obtained by *puddling;* which will make the total deficiency, by all the operations as nearly equivalent to 35. The ingots or *blooms*, which are received from the hammer, after being broken, over a small wedge-shaped block of iron called a *tup*, are placed in a species of reverberatory, very similar to the *balling furnace*, and denominated a *blooming furnace*, or *bloomery*, They are here heated to welding, and then submitted to the requisite pressure under rollers, which are either plain or grooved, according as the iron is wished to be obtained in plates or in bars. This completes the whole of the processes necessary for making the best malleable iron; and it results from the observations

which have been premised, that, in order to procure one ton of it, five-and-thirty hundred weight of *forge-pig* is previously required.

Two other modes of operating are at present in use; one of which omits the *puddling*, and the other that part of the foregoing process that concerns the fabrication of *blooms*. In the former, iron is exposed to the heat of a charcoal fire, in a species of furnace precisely similar to the one before described as a *refinery*, or *run-out-furnace*; and is continued in that situation, until the metal is thought to be sufficiently decarbonized. It is very frequently stirred during the operation; and when brought *into nature*, (to use the technicle expression) is collected into masses, and removed by tongs under a large hammer, denominated, as applied to this particular use, a *stamping hammer*, where it is beaten into cakes, which are afterwards broken up, and treated in the *balling furnace* as before described. This is the old mode of working, and the iron obtained from it is by many conceived to be of very superior quality. The heat produced is considerably inferior to that afforded by coke in the *run-out furnace*, and the iron is less surrounded by the fuel than in the case just mentioned. The present charcoal fire is properly a *refinery*, and not the one which is used merely as a preliminary to the process of *puddling*. Here the business of decarbonization is at once completed; and the resulting metal is in the same state of purity as that yielded from the rollers, after it has been *puddled* by the other method. *Balling* and *blooming* follow in regular succession, and plates or bars are produced exactly as before.

According to the second mode of treatment in which *blooming* is omitted, the masses obtained from the *balling furnace* are reduced under the hammer into the form of solid, cubical blocks; and when their temperature is too much lowered to be capable of any farther working, they

are again heated in a fire called a *chafery*, which is urged by a powerful pair of bellows, and scarcely differs from a common smith's forge, except in being larger, and the cokes upon it being heaped up to the unusual height of at least two feet. In this situation they are raised to the point of welding, and afterwards hammered out into ingots of a flattened shape. Iron bars are united to them very shortly after they are brought from the *balling furnace*, to afford a greater facility of management, in the same manner as was described in the making of *blooms*; and these, as before, are detached, when the ingot is sufficiently formed. The iron produced in this way is not considered so good as that afforded by either of the other processes, and is employed, for the most part, in the commoner services of art. Repeated rolling, or hammering, is the only means of imparting the fibrous texture so necessary to good bar iron; and as this treatment is less frequent in the present mode of operating, the deficiency of value in the material obtained may very probably be referable almost exclusively to this circumstance.

The above include the whole of the *important* variations that are presented in the manufacture of bar-iron. Other shades of disagreement may be traced in different works; but they are of a nature too trifling and unimportant to merit any particular enumeration. The art is still in its infancy; and the light of chemical science, by being brought to a focus here, cannot fail to disclose many improvements in the present modes of procedure, which will greatly abridge the expense now incident to this valuable branch of national industry. That the mere abstraction of about 4 *per cent.* of carbon should require a sacrifice, in effecting it, of above 40 *per cent.* of iron, appears monstrous beyond example: and as those who are connected with the art become more scientific in their

views, we shall unquestionably find that it will be much more economically accomplished.

When iron has been completely freed from carbon, and has acquired its highest degree of malleability by repeated hammerings, it is by far the most tenacious of all the metals, and is capable of being drawn into the finest wire.

The tenacity of iron, as well as of all the rest of the malleable metals, varies considerably according to its softness. After iron has been kept in a red heat for some time, and suffered gradually to cool, it becomes remarkably changed in point of softness. By being hammered, drawn into wire, or rolled, it increases in hardness to a certain extent; but, at the same time partly loses its malleability. By this mechanical treatment, when cold its strength or tenacity increases; and it may be taken at one point, when it will require a far greater weight to break it, than if it were hammered either more or less.

All the experiments yet published relative to the tenacity of iron, and the other metals, are on this account very defective. The writer of this article has seen an iron wire, when newly annealed, break with a weight of 50 pounds; but, after being drawn through two holes of a wire plate, bear above twice that weight, without sustaining injury. Iron, when properly annealed, will bear more bending backwards and forwards before it breaks, than in any other state: but the strength, or that power which resists a weight, exerted longitudinally to break it, is jointly as the last property and its hardness. Hence the reason why its strength is increased with a certain degree of hammering. The specific gravity of malleable iron, according to Brisson, is 7,788; that of pig-iron being 7,207. Iron, in a state of purity, requires so great a heat for its fusion, that the best crucibles are nearly ready to melt with it. It has however, been fused, and cast into an ingot. It is said to liquify at 158° of Wedgewood. Its

malleability is greatly increased by heat: and by raising it to a very high temperature, it becomes exceedingly soft, and may be brought so near to absolute contact with another piece similarly heated, that they unite firmly together. This process is called *welding*. Its great affinity for oxygen, when heated to a welding point, would very soon reduce it to an oxyd, if it were not for the vitreous matter fusing upon its surface; and it may be still more completely defended, by dipping it in powdered glass or sand."

When pig-iron has undergone either the process of the bloomery, puddling, or refinery, to dissipate the foreign mixtures which the crude iron contained—to reduce or bring to a metalline state, the particles imperfectly metallized in the furnace—and to burn away the superfluous quantity of carbon or charcoal which crude iron always contains in some part or particle of it—the metal becomes less fusible, and is carried under a tilting hammer, to be beaten while red hot: this process, frequently repeated during the period of refining the crude iron into malleable iron, has two principal effects:—1st. It squeezes out and separates, in the form of slag and scoria, all those particles which *have not* been perfectly metallized, and which therefore do not unite with the particles that *have been* perfectly metallized.—2d. It gives to the iron a longitudinal grain, and very greatly increases its tenacity. When it appears to have thus gained the properties of malleable iron, it is beaten into bars, and is ready for market as *Bar-Iron.* The loss of weight in this process obviously depends on the qualities of the pig iron employed.

In this country, tilt hammers are universally used for drawing the iron out of the loops into bars. In England they are almost exploded. The work is done by means of cast iron rollers: for which purpose (I *believe*) the fusible smooth faced pig iron, No. 1, is the best; though the grey cast iron is commonly used. In casting the rollers, the

greater weight they are subjected to, the denser and better they are: for this purpose they are usually cast with a neck of half their weight of superfluous iron, which is afterward cut off, having served as a superincumbent weight to the roller itself, for the purpose of condensing it. They are then turned in a lathe. My friend Mr. P. who was for two years a manager at Mr. John Wilkinson's iron works at Broseley in Shropshire, told me that the experiment of substituting rollers for tilt hammers in the manufacture of bars for nail rods, was made at Broseley somewhere about the year 1790; and that the same power that produced 72 ton of nail rods per week by means of hammers, produced 300 ton when applied to rollers.

Malleable iron thus produced, has the following properties.

It is a metal of a bluish white colour: it is capable of a brilliant polish: it has a styptic taste, when applied to the tongue: it has a perceptible odour when rubbed: its specific gravity varies from 7, 6. to 7, 8, the specific gravity of cast iron being about 7, 2: its specific gravity, its tenacity, and its fibrous texture, are increased by cold hammering, rather than by hammering while hot: it is magnetic: I do not know that any other metal is equally so, (steel excepted,) although symptoms of this property have been observed in nickel, and by Mr. Cavallo in brass. It has been suspected that this magnetic appearance has been owing to some small portion of iron being mixed as an impurity with the metals in question; although the experiments of Bergman and Thenard seem clearly to endow nickel with this property: when iron is well made, and hammered both hot and cold to a proper point (which may be exceeded) a wire of $\frac{78}{1000}$ of an inch in diameter will sustain a weight of 549 1-4lb: it may be fused, according to Sir Geo. Mackenzie, at 158° of

Wedgewood's pyrometer.* Iron, and platina, are the only metals hitherto known that are capable of being *welded*; that is when two pieces of iron are brought to a white heat, and placed one upon the other and strongly hammered, they become covered with a kind of metallic varnish, and may be perfectly united: iron when hot strongly attracts the oxygen or pure air of the atmosphere, and puts on a blackish blue appearance as in finery cinder, and smithy slack: these scales can be again changed into malleable iron by being treated with charcoal, which unites with the oxygen and leaves the iron: thin plates of iron may also be blued by heat without exposure to air: when exposed without heat to the air and to moisture, it is changed gradually into rust, which is either iron united to oxygen, or, as I rather believe, to the carbonic acid of the atmosphere, which exists in the atmosphere in greater proportion than is usually suspected. By heating it with charcoal, this rust also can be reduced to malleable iron. At a full red heat, iron is capable of decomposing water, uniting with the oxygen, which forms one component part of water, while hydrogen or inflammable gas which forms the other component part, is set free. The iron in this process is reduced to the bluish black oxyd of iron exactly similar to finery cinder and smithy slack. Mr. Watt, of Birmingham, told me some years ago, that iron at a white heat, would greedily attract and decompose water, if the air in the place were at all moist. These are the principal properties of the metal iron when produced by means of the processes I have detailed.

* The highest point to which I was ever able to raise an air furnace with a fuel of coke, was 172° of Wedgewood, at which heat, grains of crude platina agglutinated but did not melt; I have them still by me in a lump of about an 1 1-2 oz. weight. T. C.

Air Furnace for Cast Iron Founderies.

Fig. 2.

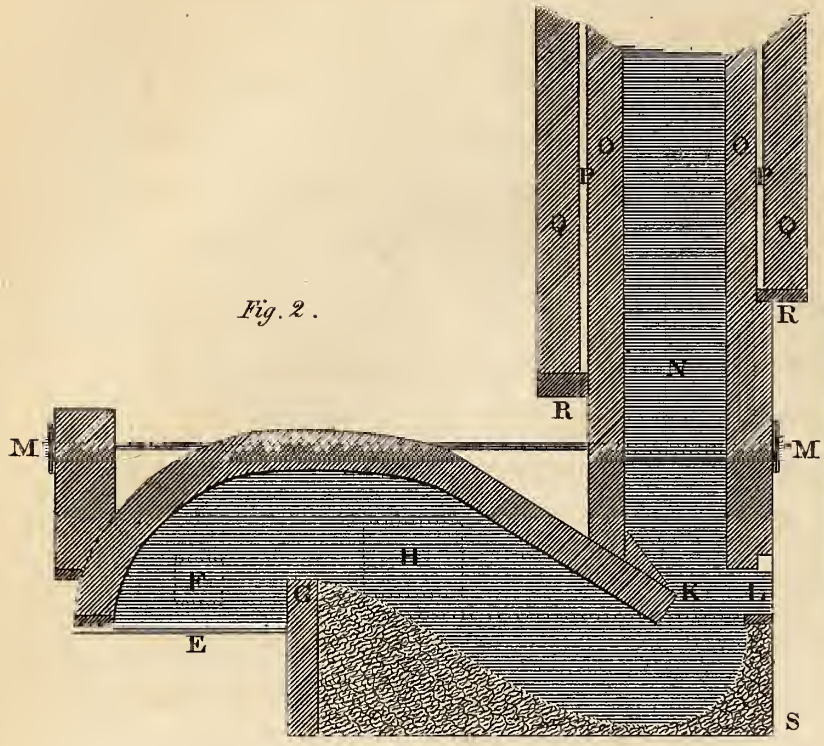


Fig. 3.

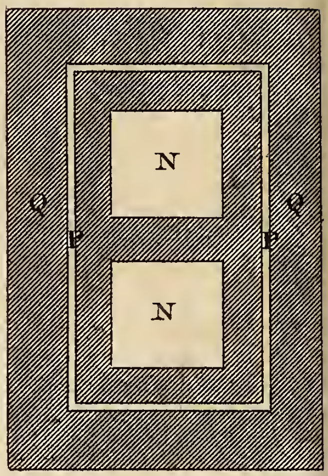
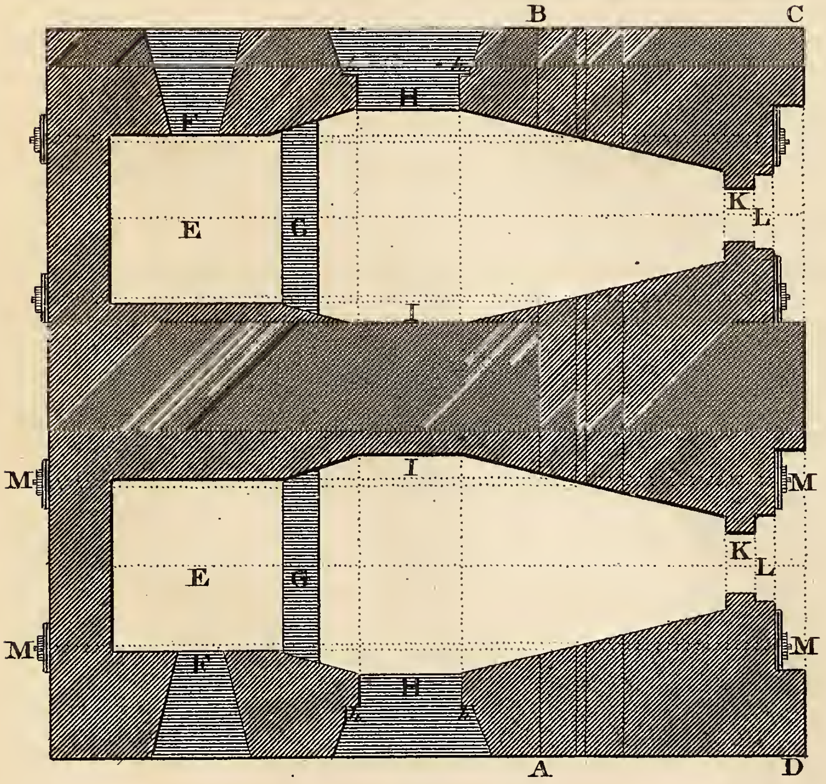


Fig. 1.



C. Tiebout

MISCELLANEOUS ESSAYS RELATING TO IRON.

On the Kind of Air-Furnaces employed in Iron Foundries for casting large pieces of Ordnance, Shafts for Mills, Cylinders, and other heavy Articles. By Mr. DAVID MUSHET, *of the Calder Iron Works.* 15 Ph. Mag.

THE furnaces about to be described are employed for melting pig-iron with the flame of pit-coal. Furnaces of this kind are constructed of various sizes according to circumstances. The small sizes will run down from seven to ten hundred weight, and are used in small foundries for what the trade call *jobbing*.

Fig. 1. (Plate IV.) a ground plan of two large air-furnaces, and chimney for melting pig or cast-iron with the flame of pit-coal.

The letters A B C D point out the exterior dimensions of the stalk or chimney, which is first erected, leaving two openings or arches into which the fore-part of the furnaces are afterwards built. The breadth of the chimney at the particular place which the plan exhibits is 16 feet from A to B, and from A to D or from B to C 6 feet 6 inches. The plan is drawn at that elevation where the flame enters the chimney by the flue or throat, narrowed on purpose to throw back part of the flame, and keep the furnace equally hot throughout, as may be more particularly viewed in the vertical section, fig. 2.

EE, the furnace bars on which the coals rest and where the combustion is maintained.

FF, openings called teasing-holes, by which the coals are introduced to repair the fire.

GG, fire-brick buildings called bridges. These are meant to concentrate the flame, that it may act as violently on the metal as possible. Upon the height of the bridge much depends in fusing the metal speedily, and

with little loss. The height of this may be seen in the vertical section, fig. 2. G.

HH, the charging doors, by which the metal is introduced in the shape and state of pig-iron, lumps, scraps, &c. &c. The iron generally occupies the furnace across to I, called the back wall, and is never meant to approach the bridge nearer than the dotted line, lest the metal in melting should run back into the grates, in place of descending into the general reservoir or cavity below. The corners or notches, *h*, *h*, *h*, *h*, receive a stout cast-iron frame lined with fire-bricks. This is hung by means of a chain and pulley, and can be raised and depressed at pleasure. This frame is, properly speaking, the charging-door, and is always carefully made air-tight by means of moistened sand.

KK, the flues or openings by which the flame enters the chimney. These are 15 inches by 10. On maintaining these openings of a proportionate size to the other parts depend in a great measure the powers and œconomy of the furnace.

LL, lading doors, by which ladles are introduced, in the case of small furnaces, to lift out the metal and distribute it to the various moulds.

MMMM, binding bolts to limit within proper bounds the expansion which takes place in the building when the furnace is highly heated.

Fig. 2. vertical section of one of the furnaces, and its appropriate stalk or chimney.

E, the grates.

F, the teasing-hole.

G, the bridge.

H, the charging door.

K, the flue or opening into the chimney.

L, the lading door.

MM, the binder or binding bolt.

N, the interior of the stalk or chimney, 30 inches square.

O O, the fire brick-work, 9 inches thick.

PP, space of 2 inches for stuffing with sand.

QQ, common brick building.

RR, cast-iron lintels, over which are thrown double 9-inch arches, so that at any time the inferior building can be taken down to make repairs, without shaking or in the least injuring the chimney.

S. The dotted lines here are meant to represent what is called the tapping-hole. When a large piece of goods is to be cast, lifting the metal with ladles would be impracticable. A sharp-pointed bar is driven up this opening. The iron then flows freely out into a large bason of sand made for its reception. It is then conducted, by collateral channels, into the mould.

The space under the curved dotted line from G to L, by S, is filled with a mixture of sand and ashes. When the furnace is prepared to melt, the whole of the bottom receives a stratum of sharp clean sand about two inches thick. This is broken up at night, and fresh sand is substituted for it before the fire is kindled in the morning.

Fig. 3. is a horizontal section of the chimney or stalk, taken where the flues assume a perpendicular direction. The letters in this figure correspond to those in the vertical section, fig. 2. The height of the chimney ought not to be less than 45 feet: if 50 feet, the effect will be sooner and of course better produced.

Remarks upon the Melting of Iron in these Furnaces.

The effect wished to be produced in air furnaces is the fusion of a certain portion of pig or cast-iron for the purpose of being poured or run into moulds to form articles of almost every description.

The preparation previous to melting is as follows:—After the bottom of the furnace is laid, and smoothed with fresh sand, and all the openings made air-tight, the furnace-man introduces a kindling at the teasing-hole, accompanied with new pit-coal. In a few minutes a considerable volume of dark flame mixed with smoke is produced. The fire quickly gathers strength; more coal is introduced; and the furnace now becomes filled with a yellow-coloured flame. By continuing this operation for an hour, or an hour and quarter, the furnace and flame will have become completely white; the latter steady, and at times apparently without motion. The furnace-man now judges the bottom to have been sufficiently hardened for receiving the pig-iron without any risk of sinking. The charging-door is now opened, and the pig-metal thrown carefully and regularly upon that part of the bottom formerly described as being appropriated for its reception. The door is again closed and made air-tight, and the operation of firing continued with unremitting care and attention.

The time of melting depends entirely upon the quantity of metal introduced. The furnaces described above are capable of melting from 50 to 60 hundred weight of metal each, and when there is a moderate circulation of air they will perform this work in 2 1-2 or 3 hours. In half an hour after the metal is introduced it assumes a blackish red colour. It then begins to brighten with every additional fire, and in about one hour appears white, and begins to lose shape, and resemble a wreath of snow.

An eye accustomed to such heats will now discern the metal beginning to drop, and run down the inclined plane in very beautiful streamlets resembling quick silver. Eight or ten of these are visible at a time, and after proceeding half way down begin to form junctions with each other, and flow connected into the general cavity or reservoir. By-and-by this becomes filled, and literally forms

a beautiful molten miror, in which sometimes part of the interior furnace is reflected.

The furnace-man, by searching at the bridge with his fire-iron or teaser, judges when the metal is nearly all gone. Of this he is certain by looking up from the peep-hole of the lading-door. If the streamlets of the running metal have ceased, then the whole is melted, and ready for running out.

In the operation of melting, the three following circumstances ought to be particularly attended to: the thinness or hotness of the metal; the waste or loss sustained in melting; and the quantity of coals employed.

The first is of the utmost importance, as many articles in the foundery business require the metal in a state of the greatest division; otherwise they will be found imperfect when taken from the sand, and unfit for sale. The furnace-man, therefore, is always on the watch to replace the fire as it decays, and keep a large and sharp volume of flame constantly passing over the metal.

The waste or loss of real metal is also an object of great importance. This always bears a relation to the quality of the iron, the strength and cleanness of the coals, and the judgment and attention of the melter. Strong iron is found always more difficult to fuse; this necessarily exposes it for a long period in contact with the flame. The reverse happens with metal that is more fragile, and easier broken in the pig. The length of the exposure in fusing depends on this; and other circumstances being alike, the loss or waste of metal will also be in the same ratio.

There are, however, other facts not unworthy of notice. No. I. pig-iron, or richly carbonated metal, when run from an air-furnace, will be found in point of quality little better than No. II. or carbonated iron. This is owing to a quantity of its carbon being destroyed during the fusion. The loss in melting No. I. iron, therefore, chiefly

consists of carbon; and the deficiency of metal ought never, with a clean bottom, to exceed 1 cwt. in 20.

Carbonated or No. II. iron also becomes deprived of a considerable portion of its carbonaceous mixture in fusion; and when run from the air-furnace is seldom better than No. III. metal. The loss sustained in melting may be averaged at 7 1-2 per cent.

No. III. pig-iron is, after melting in an air-furnace, found whitish or mottled. It is seldom susceptible of the same nice degree of division as the superior qualities, and loses in fusion a much larger proportion of metal, seldom under 10 per cent. and frequently 12 1-2 or 15.

The quantity of coals requisite to melt a given quantity of iron is various, as much depends upon the quality and fusibility of the metal. If the furnace goes one heat a day with No. I. or II. iron, the quantity of coals will be from 20 to 25 cwt. for a ton of iron. If two or three heats a day, or as many tons of iron are melted at one kindling, the proportion of coals will be nearly weight for weight of the iron melted when the coals are mixed with a fair proportion of small: with strong large splint coals, one ton of good pig-iron may be completely reduced with from 12 to 15 cwt. including the previous heating of the furnace.

Facts illustrative of the Shrinkage and Expansion of Cast Iron, &c. &c. By David Mushet, Esq. of the Calder Iron Works. 18 Ph. Mag.

THE high temperature requisite to melt cast iron has prevented the chemical and philosophical world in general from becoming acquainted with many of its habitudes and peculiarities in the different stages of manufacture. Those engaged in foundries are frequently prevented, from the hurry and bustle which attends manufactories,

from making observations, and acquire no habit of detailing them. Others again, from their earliest infancy, have been accustomed to observe, that certain appearances, time out of mind to them, had always followed certain actions performed. They acquire a laconic habit of reasoning; and if asked how such appearances are to be accounted for, their answer is, "They must exist so and so—it is in the very nature of the thing."

It is difficult to conceive a more ample field for observation than an extensive foundry. Combination, change, decomposition, combustion, and deflagration, are constantly performing their respective parts, and continually presenting matter under new and interesting appearances.

Elementary substances, subject to no real change, are modified in a variety of ways by the alternation of heat and cold. The laws which govern these are constantly exerted to produce effects equivalent to the exciting cause; and, while we often remain heedless spectators, these unerring operations are productive of phænomena which frequently elude our sagacity or puzzle our judgment.

The subject of contraction and expansion appears simple, and the presence or absence of caloric alone in the body operated upon frequently explains, in a most satisfactory manner, the whole minutiæ.

But this regards only the heating of certain substances in temperatures short of fusing them. When the object of experiment is exposed to a heat sufficient to fuse it, it then becomes subject to new laws as a fluid, and exhibits phænomena entirely different. By not taking the change of state from that of a solid to a fluid into the account, some writers have given an awkward and unsatisfactory account of the laws which regulate iron in these two different states. Before I proceed to detail some experiments made upon this subject, I shall trace out the dif-

ferent states of shrinkage and expansion, as observed in cast iron.

In doing this I shall divide shrinkage into two distinct operations: 1st, Shrinkage, properly so called, when a mass of iron diminishes or skrinks within itself, and would actually displace a smaller quantity of water, and when no degree of heat short of fusion would make it occupy its former bulk or volume. 2d, Contraction, or that diminution of superficial measurement which any body undergoes by evolving its caloric. The surface in this case is never injured; the casting will be found less than the pattern from which it was formed, and simple heating will restore it to its greatest original volume.

The former of these properties cannot exist without the latter, but this last may take effect in full force in many minor operations without any appearance of shrinkage. I only say appearance; for I believe, abstractly speaking, the one never takes place without the other, though in such various minute degrees that it is often difficult to form any estimate of the quantity.

In casting pieces of ordnance we are enabled to judge of the conjoint effects of shrinkage, contraction, and expansion. We shall suppose that a gun mould of any given length is filled with fluid cast iron not subject to these laws; then the size and shape of the gun, when cold, would exactly correspond to the dimensions of the mould, but finding that the piece of casting was considerably altered, that it had shrunk interiorly, was diminished in point of length, and had lessened its diameter, we must seek for a solution of these facts in the explanation of the causes respectively.

First assuming, what shall be hereafter proved by direct experiment, that cast iron occupies less volume when fluid than when solid; that in the act of the arrangement of the moleculæ towards consolidation, it occupies a larger bulk

than at any other period; and that when cold, and in proportion to the absence of heat, so will the volume of the metal be diminished.

1st, Then, *Shrinkage* appears to be dependent upon two causes; the gravitation of the fluid metal, and the expansion of the mould. The latter, I conceive, acts a very powerful part: the immense quantity of caloric combined with the iron is in part easily and almost instantaneously communicated through the sand to the iron box: this creates a disposition to expand, in which it is greatly assisted by the great pressure of fluid iron. That portion of the metal in contact with the interior of the mould is the first to lose its fluidity, and is acted upon and forced to give way in the same ratio of expansion before the subtle and denser fluid. The diameter of the shell of the gun is at this period increased in every part; the fluid iron in the interior descends to occupy the enlarged space, and the head of the gun presents an increasing chasm like the concave of a sand glass. In proportion as the cast iron resolves itself into a solid, a diminution of pressure should take place upon the mould: this would inevitably follow, were not its force replaced by the increased volume of the metal passing into a solid state, which is equivalent to that law which I have termed

2d, *Expansion.* Of the extent of this operation we may judge from the following facts:—All patterns of castings are made somewhat larger than the piece of goods is wished to be: in common cases 1-8th of an inch to the foot is allowed, but in many cases the allowance will be nearly 3-16ths of an inch. In the case of the gun, therefore, the mould would be plus the allowance upon the pattern what space was gained by beating the pattern to loose it from the sand, and all the extra space acquired by the increased volume of the consolidating iron. These, taken collectively, may amount to 1-4th or 5-10ths of an inch;

and so much less will the diameter of the gun be found when cold, to what it would have measured at the climax of its expansion.

3d, *Contraction* immediately takes place of the metal ceasing to expand: to its effects are chargeable the reduction of the increased diameter of the gun, and which seems merely in consequence of the escape of the caloric.

The action or effect of these separate laws will intimately depend upon the quality and fluidity of the metal: with the same quality of iron different effects will be produced according to the division of the fluid, and with the same degree of division in the fluid the extent of the operation of these laws will be different with the different qualities of crude iron. Soft cast iron very hot will shrink and contract less than iron equally hot but of a harder quality, or, which is the same thing, than iron containing less carbon.

In casting cylinders, pipes, and other hollow machinery, the effects of expansion and contraction are manifested without any great degree of shrinkage appearing.

The diameter of the mould in all these castings is generally made from 1-8th to 3-16ths per foot in diameter larger than the casting is wished to be; while the space or vacuity left betwixt the exterior and interior of the mould, called the thickness, is made less than the strength in metal is wished to be.

When the cylinder is cold, however, the diameter, if properly allowed, will be found correct by the operation of contraction in cooling; while the thickness in metal will be found increased, though still correct, by an expansion or separation of the exterior and interior parts of the mould. This last is by the moulder called *straining;* and if great care is not taken to compress the sand firmly round about the mould, the thickness is sometimes increased so much as to render the manufacture unsaleable. Should this

necessary precaution be slightly performed, and the thickness considerably increased, the usual expansion which takes place when the metal passes into the solid state becomes so extensive as to effect a permanent increase of the diameter of the casting, and destroy its use*. The united effects of these two causes force the sand to assume an elevated posture all round the mould, and occasion violent rents and fissures, which become immediately filled with pale blue flame, accompanied by a crackling noise like the snapping of electric matter.

Shrinkage in these castings, particularly if large, would affect the solidity of the vessel by taking place to a considerable extent upon the upper surface, immediately where the runner discharges the metal into the mould. This is in a great measure counteracted by feeding these *gates* or *runners*, after the mould is filled, with several ladles full of fluid iron, and keeping the communication open to the edge of the casting by moving small iron rods up and down in the *gate*. The metal is thus allowed to percolate into the chasm, if any is formed, and prevents any bad consequences likely to ensue from the general shrinkage of the mass.

It is impossible to convey an exact idea of the extent or quantity of shrinkage that takes place in castings, or proportion it to the weight or dimensions of the original mass. The subject of contraction is more within the reach of measurement, and in many cases may be ascertained with great precision.

* The additional thickness always takes place to the exterior of the mould. The pressure can more easily act with effect against the concave than the convex side of the mould. The moulder is fully aware of this in the act of cooling, particularly if the metal has been very hot and of a sharp quality. After he conceives the iron fairly consolidated throughout, he cuts two openings at least in the core or interior part of the mould, and penetrates to the red-hot surface. This gives scope to the contraction of the vessel, and preserves the casting frequently from being destroyed.

The following bomb-shell gauges were cast from very clean wood patterns; the breadth of metal in the hoop was exactly 1·250 inches, and the thickness ·450 inch.

Diameter of Patterns.		Diameter when cast.	Contraction.
1st Pattern	7·500 inches.	7·350 inches.	·150 inch.
2d ——	5·950	5·850	·100
3d ——	5·500	5·430	·070
4th ——	4·550	4·490	·060
5th ——	4·060	4·020	·040

The relative proportion of contraction to the diameters will be as follows:

Contraction of No. I.	·15,	equal to	1-50th of the diameter.
II.	·10,	——	1-59$\frac{1}{2}$
III.	·07,	——	1-78$\frac{51}{100}$
IV.	·06,	——	1-75$\frac{83}{100}$
V.	·04,	——	1-100$\frac{1}{2}$

It will be seen from this table, that the quantity of contraction is in a due relation to the diameter of the casting. No. IV. seems an exception, however, and appears to have shrunk more in proportion to its diameter than the other four. This may with safety be laid to the score of error in the moulding. In casting flat surfaces, the degree of contraction is in a just proportion to the length of the article.

	Inches.
A front pattern of polished tin measured exactly	24·5
When cast of soft grey iron, and cold, measured	24·250
Contraction	·25

Equal to 1-98th part the length of the pattern; the height of which, or rather breadth, was 20 inches; its thickness a quarter of an inch.

The contraction of two ash-grate patterns was ascertained as follows:

First pattern measured in length -	18·250 inches.
When cast in soft iron - -	18·035
Contraction	·215

Equal to 1-84$\frac{88}{100}$th part the length of the pattern.

Second pattern measured in length -	11·100 inches.
When cast in soft iron - -	10·975

Equal to 1-88$\frac{87}{100}$th part the length of the pattern.

The breadth of No. I. was 11 inches, that of No. II. 8$\frac{1}{2}$ inches ; the thickness in both was ·475 inch.

I shall now finish this paper with some experiments made upon the casting of cannon shot. This operation is performed by pouring the liquid iron into a mould which is divided into two semi-spheres. The mould is possessed of a joint, which preserves the sphericity of the shot. It is formed by careful turning to gauges made with great care and exactness. This operation exhibits very distinctly the laws of shrinkage, contraction, and expansion ; and from it I mean to prove the truth of what I only before assumed : 1st, that cast iron, when fluid, is then more dense than in any other state : 2d, That immediately upon its passing from the fluid to the solid state it acquires its greatest volume ; and 3d, That when cold, and always in proportion to the absence of heat, so will be the diminished diameter of the shot.

To prove that cast iron is denser in the fluid state, several pieces of iron may be put into a ladle, and hot fluid iron poured upon them ; they will immediately rise to the surface, and expose a considerable portion of their bulk above the surface of the liquid iron. This buoyancy diminishes ; and as the pieces of metal approach more and more to the state of fusion that exists in the ladle, they gradually sink till they disappear entirely under the surface ; they then rapidly dissolve, and form a part of the fluid iron.

Melted cast iron supports also lead and tin in the same manner ; but these soon become dissipated in the great heat of the fluid.

If a 6-pounder shot is placed in the bottom of a 12-pounder mould, or of any size larger, and hot melted metal poured in till the mould is filled, apparently a perfect shot is formed; but a few blows upon the upper part of the sphere, around the gate or runner, detect the surface of the small shot. The thickness of the iron here will not exceed 1-10th of an inch, while the bottom thickness will be nearly a full inch; and if the mould exceeds in diameter that of a 12-pounder, the inequality of thickness is greater. It is evident from this, that six pounds of fluid iron float six pounds of solid iron in the state of a sphere. That this property is permanent, may be further understood from a continuation of the same experiment. If a short allowance of time is made after the mould is filled under the above circumstances, and this dexterously inverted, a fair inclosure will be found, possessing regular and equal thickness of new metal on all sides of the minor ball.

This is easily accounted for upon the same principle. When the mould was full, the ball, as usual, occupied its place near the runner. The iron first run into the mould, meeting with the greatest degree of cold, would immediately consolidate upon the bottom: when the mould was inverted, the ball would naturally tend to elevate itself to what was formerly the bottom of the mould; but its progress would be arrested by that portion of the iron now become a solid, and would remain stationary, more or less central in proportion to the fitness of the moment taken to perform the operation.

That cast iron occupies a greater bulk of volume immediately after it passes into the state of a solid, may be learned from observation as well as direct experiment. If a shot-mould is carefully separated at a certain period after filling, a metallic crust is formed, more or less thick, which is the natural progress of consolidation, but which

is at present an envelope to a considerable portion of fluid contents. In this state the expansion, if any has taken place in the shot and mould, is nearly the same; the former is easily extracted from the under and upper parts of the latter. In about two minutes after, however, the expansion of the shot is more rapid than that of the mould; and at this period is difficult to disengage. As the heat is communicated to the mould, its dimensions enlarge, and the extraction of the shot is attended with less violent efforts. The mould is always filled by the shot till cooling has so far taken place as to reduce the shot-mould to its former diameter. Beyond this, however, the shot still continues to lessen its bulk, so that when cold it will be found to have left its mould by nearly 1-66th part of its diameter. In all cases where shot-moulds are re-filled before they have contracted, by cooling, to their original diameter, their product in shot will be various as to dimensions. The effects of this, particularly in summer, are inconceivable, and though seldom adverted to, will account often for shot being rejected as unserviceable for not passing the gauge. This subject I at one time paid particular attention to, and, to ascertain the fact rigorously made the following experiments:

I selected seven pairs of shot-moulds, well seasoned, of the following sizes, 3, 4, 6, 9, 12, 24, and 32-pounders. These were cast or filled with the same quality of iron three times successively. The first interval of pouring was ten minutes, and the second fifteen minutes.

		Measured.	Weighed.	
		Inches.	Lbs.	Grs.
3-pounder shot,	1st Cast	2·724	2	6015
	2d ——	2·730	2	6031
	3d ——	2·736	2	6070
4-pounder shot,	1st ——	3·036	3	6125
	2d ——	3·054	3	6234

	3d ——	3·087	3	6289
6-pounder shot,	1st ——	3·240	5	4813
	2d ——	3·240	5	5031
	3d ——	3·290	5	5250
9-pounder shot,	1st ——	4·032	8	5906
	2d ——	4·050	8	6016
	3d ——	4·090	8	6236
12-pounder shot,	1st ——	4·440	11	5250
	2d ——	4·444	11	5480
	3d ——	4·512	11	5781
24-pounder shot,	1st ——	5.556	23	3830
	2d ——	5·574	23	4485
	3d ——	5·666	23	5690
32-pounder shot,	1st ——	6.114	31	5360
	2d ——	6·156	31	6343
	3d ——	6.268	32	1530

Upon this table I have only to remark, that the ratio of effect, both in the expansion and increase of weight, is exactly analogous to the weight or diameter of the ball, or, in other words, to the mass of fluid iron poured into the mould. When the last round of pouring was finished, the moulds possessed a temperature respectively to their sizes. The 32-pounder mould was thoroughly red-hot, though nearly two inches in thickness and weighing 140 pounds. In this and in the 24-pounder mould a curious species of adhesion had taken place in the bottom, betwixt the shot and the mould, by the moulders called burning. When the bullet is broken off, the mould exhibits an elevated spongy mass which resists the hardest tempered steel.

About two years after the above experiments were made, I paid particular attention to the effects likely to be produced in a large way in the usual train of manufacture. My observations were conducted in a shop appropriated for shot-casting. The length of the house was 30 feet,

breadth 16, side walls 8 feet, with a pavilion roof of the common range.

The work performed here was the filling of about 150 pairs of moulds, of all sizes, three times each day. These occupied the floor of brick in different ranges, and presented a very large aggregate of heated surface when poured. The quantity of metal thus formed into shot at each cast was nearly a ton. In May 1796 the average temperature of this workshop for several days during casting was 115° Fahr. One day a spirit-of-wine thermometer burst in my hand with a report like a pistol. Its greatest range of scale was 120°: the passages betwixt the moulds, for the movements of the pourers, were 130°. In all these extra temperatures I uniformly observed that a considerable portion of the shot, particularly in the third cast, passed the gauge with difficulty, and many of these found unserviceable for carronades, where the windage allowed upon the calibre of the piece is less. In the middle of August in the same year, during a period of very hot close weather, I made repeated trials, and found the effects always proportioned to the temperature of the workshop. I shall finish this paper with the particulars of one day's observations.

		Temp. of Room.
1st Cast, 9 in the morning	- -	65°
in 5 minutes of casting rose to		80
in 10	to	112
in 15	to	128
in 20	to	140
Greatest heat in 35 minutes being three minutes after the pouring had ceased,		156

From 128 to 156° I felt a sensation of cold similar to that when approaching a fire in winter, accompanied by a considerable degree of shivering. About 150° this sensation wore off, and I felt comparatively comfortable. Per-

spiration had now become so violent as to ooze through all parts of my waistcoat, breeches, and stockings. The workmen who carried the metal perspired in such a manner as to wet their large sacking trousers as if they had been soaked in water. The moisture ran in such torrents from their faces and arms, as to be distinctly heard hissing upon the heated moulds. Their step and arms were more agitated than I had ever before observed, and the sinews all over their bodies were uncommonly large, and felt inflated to a great degree. Two men performed the whole labour of pouring; so that each of them in 32 minutes carried half a ton of metal in quantities, in hand-ladles, from forty to fifty pounds each time. The space gone through each time, the return with the empty ladle included, was nearly 120 feet, or fully equal, upon the whole travel, to half an English mile: the half of which space was traversed with a ladle, metal included, weighing 80 pounds. One of the men, immediately after this operation, emptied a pitcher of spring water at one draught which I estimated at five English pints.

The phænomena of the 2d cast were not so marked. So much is the human body the child of habit, that I neither felt the same extent of sensation, nor remarked it upon the workmen, although the thermometer maintained itself for some minutes at 158°. In the afternoon the air began to circulate, and the temperature of the shop became much more moderate. The third cast, however, soon destroyed this pleasant change, and, before half done, the thermometer rose to 164°. Still the workmen seemed to suffer less than in the morning, except on the legs. Most of the ranges of large moulds were throwing off the caloric in ruelle undulations, and exhibiting symptoms of approaching redness. The smallness of the shop admitted only of 2 1-2 feet of passage betwixt range and range; which made the temperature of this spot intolerable.

When the cast was finished I had the doors and windows shut. This made the real state of the moulds visible. The 18, 24, and 32-pounders were all of a dark glowing red heat, and presented an arid and inhospitable glare with which it was impossible long to exist.

Some Account of the Manufacture of Forged Iron Vessels, at Fromont. By M. CH. HERSART.*

THE operations of forging vessels of cast iron may be divided into three distinct parts: 1st, the method of forging the plates; 2d, that of forging the cake or parcel; 3rd, the cold hammering. Of these we shall speak in the order here mentioned, which is likewise the order of fabrication.

To Forge the Plates.—The iron for this manufactory must be very soft and malleable. It has usually the form of bars, ten or twelve feet long; each bar having the form of a long truncated square pyramid. This form is necessary in order to obtain plates of different diameter. The small base is a square of ten lines, or twelfths of an inch, and the greater eighteen lines.

The assistant puts one of these bars in the fire, and when the heated part is ignited, the master forgeman carries it to the small tilting hammer, which is not different from those used in drawing out steel bars. He places the bar on the anvil, not upon one of its faces, but on an edge, as, in this position, the iron is less subject to crack. According to the size of the plate intended to be hammered out, the workman strikes a greater or less portion of the bar, presenting it in all situations to the hammer, in order that the plate may obtain a circular form. Between the plate

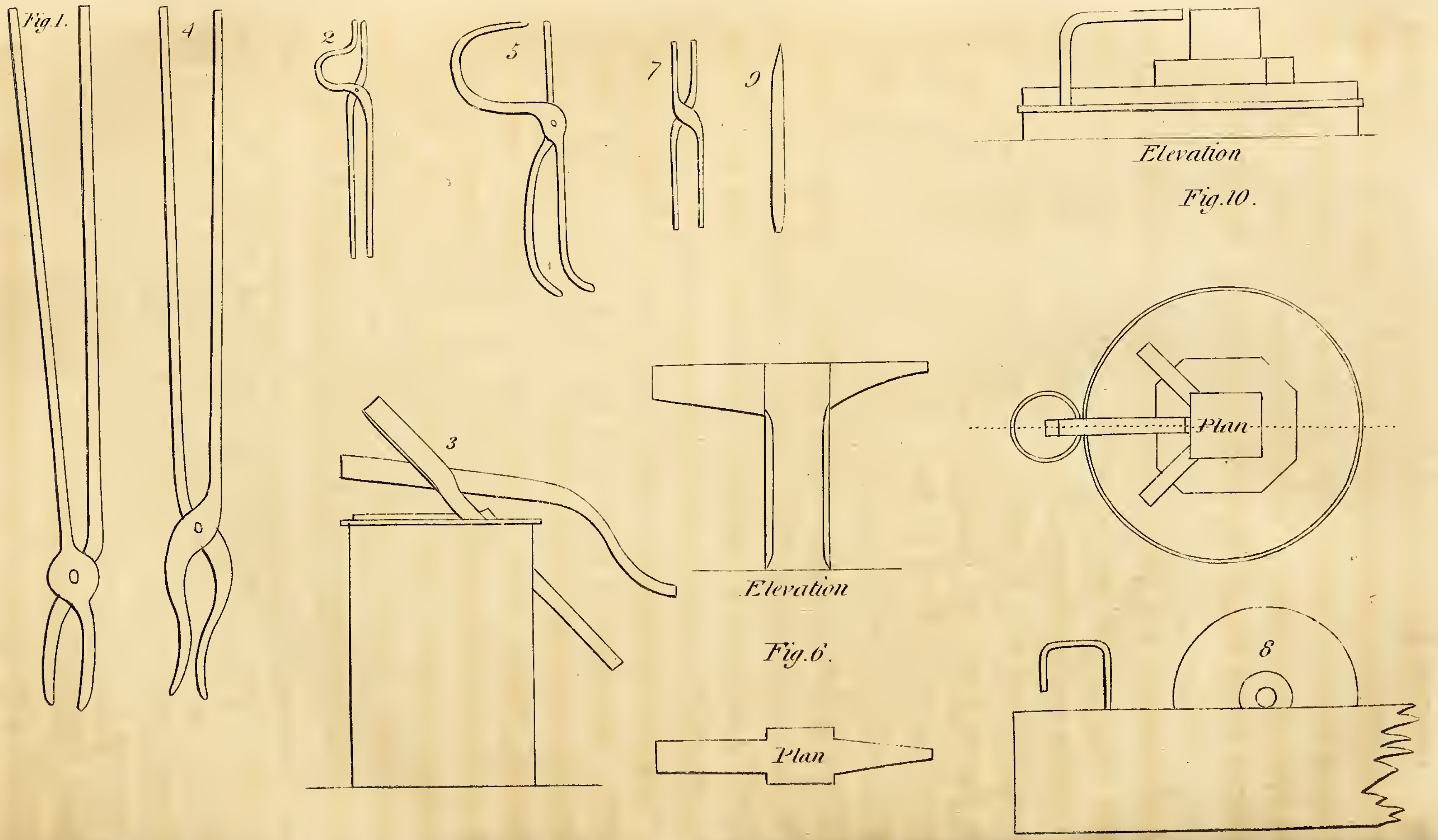
* Journal des Mines, No. 112.

and the bar itself, he fashions a small neck to facilitate its separation. In this manner, the workman continues to forge the plate on both its faces as long as the heat allows, after which he carries the bar to the anvil, and applies a cold chissel to the neck, upon which his assistant strikes in order to separate the plate from the bar. This last is then returned to the fire, in order to continue the operation in making a second plate. Sometimes, but this is only when the plates are small, the workmen make three at once.

When a sufficient number of plates has been thus fabricated, as they are of different sizes, namely, from three or four inches diameter to a foot, the workman disposes them in parcels, of which each contains four of equal dimensions, and then carries one of them to the hearth of the furnace, where the assistant takes them in the large tongs, Fig. 1, Pl. VI, and puts them into the fire, taking care to change their position often; and when the brass is red hot, the master workman, who holds a small pair of tongs in each hand, carries it under the tilting hammer, after having spread charcoal powder between the plates, to prevent their welding together. The two pair of small tongs have the form of Fig. 2 and are used to give a circular motion to the parcel, and to keep it on the anvil. When he has finished hammering it, he changes the order of the four plates, and in making this change, he is careful to take notice whether any of them have cracked; and where he perceives any crack, he applies the cold chisel, or a wedge to the place on which the assistant gives a blow.

After having changed the situation of the plates in such a manner that the two outside plates become the interior ones, he places this parcel on the hearth, and takes another set, which the assistant has caused to be heated, and he subjects this to the same operation of the hammer. In

Manufactory of forged Iron Vessels.



this manner the process is conducted until the required dimensions are obtained, namely, after five or six heatings. He then places the plates on the ground to cool; and when cold, he cuts them circularly one at a time, with the large hand-shears, Fig. 3.

This being done, each face of the plate is severally covered with a mixture, formed of the oxide of lead and the oxide of tin, pulverized and mixed with a little water; or, instead of this mixture, clay, diluted in water, may be used, as I have seen practised. Either of these will prevent the plates from welding together, and for that purpose it is that they were applied.

Forging the Cake. The workman takes seven plates of the same size, coated as before described, with the oxide of lead and tin, and he places them upon each other. These seven being placed on two others of larger size, constitute what is called a cake, which is put into the fire by means of large tongs, not differing from the former, except in the mouth, or claws, which are rather higher and curved, as is seen in Fig. 4.

When the cake is red hot, the assistant, who always has the management of the fire, takes it to the edge of the furnace, where the master workman bends the two large plates in one part, and takes up the cake with the tongs already mentioned, Fig. 2. when he carries it to the anvil of the small forge hammer, in order to bend the edge of the two great plates entirely round. The difference between the diameter of the great and small plates, is about two inches; when this is done, he puts the cake again into the fire; and when red hot, he carries it to a smaller caking hammer than that used before, but fixed and moved in the same manner. The anvil is a rectangular parallelopipedon, which rises above the ground not more than one foot; and it has three pieces of iron bended to a right angle, at the height of the angle, which affords three branches

converging towards the anvil, and serving to facilitate the operation of moving the cake during the work next to be described. See the plan and elevation traced, Fig. 10.

The workman being seated before his hammer, takes the cake with two small pair of tongs, and gives it a continual circular motion: during this commencement of the work, he hammers it only on the edge, after which he ignites it, he again carries it to the same hammer, first wetting the edge of the plates to diminish the heat which would only incommode him. By this second forging, he carries his stroke nearer to the centre still continuing the circular motion. By repeating the same operation as far as for eight times, continually approaching the centre, the edge rises every time, and the assemblage of plates become more and more hollow. Accordingly, as this figure encreases, he finds it necessary to change his tongs for others, which differs from the first in the elevation of one of the jaws, and the extremity of the handle, Fig. 5. After seven or eight ignitions, he carries the cake to a kind of anvil, the form of a figure 6, where he holds it with small tongs, Fig. 7, in order to complete the sides, which is done by the workmen hammering in succession; the hammer of the assistant being heavy and double-handed, when this is upon two at once. It is speedily done, and followed by another nearly similar on the bottom of the vessel, by a second hammer, placed near the first, striking on a kind of square anvil. Young girls, afterwards, are employed in scraping the bottom with an iron rod, Fig. 9. One foot and a half in length, terminating at one of its ends in a flattened small termination of steel. After this is done, the workman takes three vessels, one after the other, and presents them under a third hammer, placed near the two first, and moved like them by the same arbor, which carries a small tripping wheel, moved by water. The vessel is placed on the anvil, so that the

hammer, which is pointed at its striking extremity, enters into its cavity. The workman holds the vessel, and shifts its position with his hands and knees. Every stroke of the hammer leaves a slight cavity of the size of a pea, which forms different designs, according to the motion which the workman gives to the vessel. These outlines are not made for the sake of beauty, but to give strength and firmness to the vessel by hammer hardening it. The young girls, afterwards, take the vessels and scrape the interior sides, as was done with the bottom; and lastly, the workmen, on two kinds of anvils, the one plain and circular for the bottom, and the other semi cylindric for the sides, completes their figure with a wooden mallet. Small cracks sometimes appear in the vessel, which the workman close, and the matter is suffered to cool; after which, the cake, which now has the form of a tuencated cone, is carried against a piece of iron bended two ways, Fig. 8, and drove into the wooden block, which supports the gudgeon of the arbor of the hammers. This doubly recurved iron serves to retain the cake which enters under it, and by that means allows the small tongs, Fig. 7, to raise up the edges of the two great plates, which, in part, covered the seven small ones. This being done, the vessels, or hammered pieces, are taken out from within each other. The first is always perforated on account of the immediate purchase of the hammer, and that of the air, which partly converted into scales, fall out by the immediate action of the hammer. As these vessels, when taken out, are more or less bended, the assistant sets them to right by a few strokes of the hammer, after which the master workman cuts their edges with the shears.

Cold Hammering and finishing.—After the vessels are cut round, they are delivered to another workman, who takes them to his separate shop to finish. His first operation is to set the conical surface fair by means of a small

hammer, upon a proper tool. The workman holds the vessel with his right hand with his small tongs, 7; and with his left hand, without tongs, taking care to turn it round continually. Sometimes he performs this operation with a stroke of the hammer; and the complete finish is made by cutting the edges with scissars, similar to those before described.

The furnace made use of is a simple forge furnace, and the fuel is charcoal of fir, excited by wooden bellows.

STEEL.

Preliminary facts and observations.—I have already given some useful notices concerning charcoal. But I think it right again to resume the subject, and to consider it in a point of view more strictly chemical. I do this, in the outset of the consideration of the manufacture of steel, because I consider steel, as PURE IRON, CHEMICALLY UNITED TO PURE CHARCOAL. Pure charcoal, free from earth, ashes, water, oxygen, atmospheric air, or hydrogen, (the substances with which common charcoal even when well burnt, is usually contaminated) is called CARBON by the chemists, and is found naturally in its greatest purity in the diamond; which however Mr. Davy has lately found to contain a very small proportion of earthy matter.

Carbon then is contained in wood; in stone coal; in well burnt charcoal of wood; in well burnt charcoal of pitcoal; in animal substances and the charcoal of animal substances; in the diamond; in plumbago or black lead; in the carbonic acid. The carbonic acid, is united in a solid state to chalk, marble, and limestone; and frequent-

ly also to the ores, calces, and precipitates of many metals; it is found also as the base of the carbonic acid gas which exists in the atmosphere in the proportion of about one part in 100; also in the gas which is produced during the fermentation of vegetable substances; in the air expired from the lungs; in the air evolved from burning fuel; in the choak damp of wells and mines; and perhaps in some other ways, not necessary to be noticed here. In all these substances whether solid or aeriform, the carbon or pure charcoal is one and the same thing.

Carbon united with oxygen in a high degree of heat, becomes carbonic acid gas, the choak damp of mines, which extinguishes flame, and animal life, and exhibits slightly acid properties. The form of air or gas, which the carbonic acid puts on, is owing to its combination with caloric or heat.

The method of ascertaining how much carbon exists in a given substance, is by uniting it with oxygen, (or the pure air which forms 21 parts in 100 of the atmosphere) and then ascertaining the quantity of carbonic acid gas produced; this can be done by means of lime water, which absorbs the carbonic acid gas, and the lime becomes again limestone. For lime is limestone deprived by fire, of water and carbonic acid.

The method of acertaining how much carbon or pure charcoal is contained in iron or in steel, is by dissolving a given weight (100 grains for instance) in oil of vitriol diluted with six times its bulk of water, which will dissolve theiron and leave the carbon or charcoal undissolved in the form of a black powder.

The rough method of making charcoal, is by piling billets of wood on an earthen floor, leaving an opening in the middle of the pile by means of placing the billets slanting toward each other, so as to make the pile nearly a cone with a wide base. Fire is put in at the top of the middle

opening. The pile is covered with earth all round, leaving just vent enough here and there for the fire to spread and to dissipate all the acid of the wood, the water, the oil, the air, &c. but without consuming the substance so as to destroy its bulk or shape: this requires the attention of 3 or 4 days to burn 150 or 200 bushels at a time of charcoal. The lightest woods (generally speaking) make the best charcoal. The charcoal thus burnt, should preserve the shape, and texture, and fibre of the wood. It should be of a deep shining black colour, light, dry, brittle, porous, giving out a ringing sound when struck, and frequently hard enough to strike fire with steel. Hence its powder is used by mathematical instrument-makers, and engravers, to polish their brass and copper; also to polish horn, &c.

This method of making it, is not sufficiently nice and accurate for the purposes of gunpowder. In that manufacture, the wood is distilled in large iron cylinders, to which a tube is adjusted, and the substances distilled over, are detained in close vessels, being chiefly, an acid liquor sold to the callico printers under the name of pyroligneous acid, water, and oily matter. The heat given is very strong; and in this way, all access of common air is prevented. The charcoal is very light, very black, and comparatively very pure, containing nothing but carbon, with a small quantity of ashes and earth.

In the common method of making charcoal, much of it is very imperfectly burnt, still containing moisture, hydrogen, atmospheric air, oily matter, and pyroligneous acid, that is, the acid liquor distilled from green wood by means of heat. The carbon of the wood also becomes oxygenated by decomposing moisture during the process of making charcoal, as well as by imbibing atmospheric air; which it requires a high degree of heat to drive off; the

heat employed in burning wood into charcoal is not sufficient for this purpose.

The best burnt charcoal also, exposed to the air, gains 13 per cent. in weight by imbibing moisture from the air, as well as the air itself.

Hence in a gross way, even good charcoal as it is employed at the furnaces in this country, may be regarded as containing by weight, 15 per cent. water and air of various kinds, oxygen and hydrogen ; 15 per cent. earth, ashes, and imperfectly-consumed impurities ; and 70 per cent. carbon. The water and atmospheric air would be in greater proportion, if the charcoal were purer ; for good charcoal imbibes them with avidity.

From the very accurate experiments of Messrs. Allen and Pepys, which nearly confirm those of Lavoisier and Smithson Tennant, (but not those of Morveau) it appears, that the following woods put into a crucible and covered with perfectly dry sand, exposed for 20 minutes to a red heat, and then for 40 minutes to a white heat, yielded of charcoal as follows :

	Per cent.
Fir-wood (white pine) yielded of charcoal	18·17
Lignum vitæ - -	17·25
Box - - - -	20·25
Beach - - -	15.00
Oak - - -	17·40
Mahogany - - -	15·25

It also appears, that perfectly charred willow wood, weighed while hot, gained 12 1-2 per cent. in weight, on being exposed to the air for 52 hours, and this additional weight proved to be chiefly water.

Also, that in the common atmospheric temperature (60° of Fahrenheit) barometer at 30 inches, 100 grs. of carbonic acid gas may be considered as containing 28·635

grains of pure charcoal, the diamond furnishing but 100 grains of the same gas, from 28·825 grains of diamond.

Also, that at the same temperature, 100 cubic inches of carbonic acid gas, weighs 47·26 grains, and 100 cubic inches of pure air or oxygen gas, weighs 33·82 grains.

By my own repeated experiments I find that good limestone, such as white marble, may be considered as containing 43 per cent. of carbonic acid gas in a concrete state (that is uncombined with the quantity of caloric or heat necessary to render it gaseous or bring it to the state of air.) Hence every 100 parts by weight of good limestone, contains upwards of 12 parts by weight of pure carbon or charcoal, a consideration not commonly or sufficiently noticed. But owing to the size of the lumps in a charge at an iron furnace, and allowing for impurities, I do not think that 100 even of good limestone will yield in the usual heat of the furnace more than from 35 to 38 of carbonic acid gas, containing about 11 per cent. of pure charcoal. I would further observe, that where the slag is an uniform dense glass, without blebs, all the limestone is deprived of its carbonic acid, for though oxygen or the base of pure air, *will* unite to glass, carbonic acid *will not*. *Pure* limestone precipitated from a solution in acids by a solution of pearl-ash, contains nearly 44 grains of carbonic acid in the hundred.*

From the same experiments of Messrs. Allen and Pepys it appears, that 100 grains of carbonic acid gas

* To try your limestone: Take 100 grains in powder, dissolve it in a mixture of 1-2 spirit of salt and 1-2 water. Wash with a pint of hot water what remains undissolved, and dry it for an hour in the heat of boiling water. Weigh it, and it gives the weight of the impurities. This method may be checked, by throwing down the limestone by means of a solution of pearl ash, wash and dry it: weigh it: the weight added to the impurities ought to make up 100 grains.

were produced from the combustion of 28,235 grains of welch coal, which is a graphite or anthracite coal, burning with little or no flame or smoak, and similar to the Lehigh and Wilkesbarre coal of Pennsylvania, or the Kilkenny coal of Ireland. Also that 28,46 grains of plumbago or black lead produce 100 grains of carbonic acid gas; the additional weight in these cases arising from the oxygen employed in the combustion, and united to the carbon. Also that pure well burnt charcoal of wood, made in a white heat in a close vessel, and weighed while it is still quite hot, consumes as much oxygen to convert it into carbonic acid, as the diamond does within $\frac{19}{100}$ of a grain in 100 grains. Hence, that whatever imperfectly made charcoal may be, pure, well-burnt charcoal made as above, is not an oxyd of carbon, and contains no hydrogen.*

By the experiments of these gentlemen, 100 parts of animal charcoal carefully made from muscular flesh does not contain more than 67,5 of carbon and produces 23,72 *per cent.* by weight of carbonic acid gas, but I suspect ani-

* The following brief notice of the use of charcoal may be crouded into a note.

It is the best tooth powder known when used fresh. It takes away the smell of putrid meat. Three times I have boiled legs of mutton, offensive to the scent, in hot water containing a shovel full of live coals taken from the bottom of the (wood) fire: when boiled for 10 minutes, the meat taken out, and wiped, the stinking water thrown away, and the boiling repeated in the same manner; the mutton became eatable. It takes away the peculiar flavour of bad spirits. Charred casks keep water a long time fresh. Meat suspected as liable to become putrid, is better kept in charcoal than in any other way. It is an excellent non-conductor of heat, and therefore should be used for lining the outside of vessels, wherein ice or cool liquors are required to be kept. Animal charcoal, as of bones (fresh made ivory black) peculiarly answers, for clearing and fining vinegar.

mal charcoal is decomposed by a less heat than charcoal of pine or oak; a consideration that I regard as of great importance in this country, both as to the facility of making steel, and the economy of wood. From some experiments of Vauquelin, steel seems to contain phosphorus; if so, it was probably made by animal charcoal; which is always preferred for case-hardening.

That steel, whether cemented steel, or cast steel, is merely charcoal combined with iron, will appear from the various processes of making it. But the fact can be proved by direct experiment. Take 100 grains of filings of pure malleable iron; as much of cemented or blistered steel; as much of cast steel. Dissolve each of these separately in spirit of salt and water, half and half, in a warm place. The solution of the iron will furnish no black powder remaining undissolved; the two other solutions will; and the cast steel the most. Pure charcoal is not capable of being dissolved in any acid.* Indeed the common mode

* The following facts relating to the indestructibility of charcoal, are well worth attending to. "The beams of the theatre at Her-" culaneum were converted into charcoal by the lava which over-" flowed that city, and during the lapse of between 17 and 1800" years, the charcoal remains as entire as if it was made but yester-" day, and will probably continue so to the end of the world. The" incorruptibility of charcoal was known in the most antient times." The famous temple of Ephesus, was built upon wooden piles" which had been charred on the outside to preserve them. 3 Wat-" son's essays 48.

"It is said there still exists charcoal made of grain in the time" of Cæsar, which is in so compleat a state, that the wheat may be" distinguished from the rye. Willich.

"About 40 years ago, a quantity of oak stakes were found in the" bed of the Thames in the very spot where Tacitus, says that the" Britons fixed a vast number of such stakes to prevent the passage" of Julius Cæsar and his army. They were charred to a consi-" derable depth, retained their form compleatly, and were firm at" the heart. Dr. Robison.

of trying whether a piece of metal be steel or not is a proof of this. Clean the surface; put on it one drop of common aqua fortis; let it remain a minute; wash it (without rubbing it) in water; if it be iron the spot will be white; if it be steel the spot will be black, from the undissolved carbon.

If then steel be a composition of iron and carbon, can it be made by means of any thing that contains carbon? It can.

1st. The common method of making steel is by cementing iron bars with charcoal, and applying a strong heat.

2dly. The French chemists say that they have made it at once from malleable iron, by means of limestone and bottle glass. English cast steel is made as I have been told, by melting blistered steel with powdered limestone mixed with powdered glass.

3dly. I have seen at Birmingham steel made by passing steam into a furnace in which iron was in a state of fusion; the steam being decomposed by the charcoal, furnished carbonic acid gas which in its turn was decomposed by the iron. But this process did not answer in a large way, either in point of economy, or uniformity of product.

4thly. Steel has been made, by mixing a small quantity, of diamond powder with malleable iron; this experiment has been repeated both in France and England.

5thly. It has been made by mixing black lead with malleable iron, and exposing the mixture to a melting heat.

6thly. By mixing one-fifth part of kishy, supercarbonated smooth faced crude iron, with common malleable iron.

7thly. It can be made with the charcoal of hoofs, horns, woollen, bones, or any other animal substance: and as

The writings of the antients were with atramentum made of glue and lamp-black, or powdered charcoal, and they are now perfectly black. See Parke's Ch. Catech. 267.

these give out their carbon with a less degree of heat than the hard charcoals of wood, they are sometimes used in the steel furnaces of Pennsylvania, where the only reasons why steel is not made as good as in England, are, 1st, the want of heat sufficient from a wood fire; 2dly, the use of iron not sufficiently pure in quality, or well hammered in the bar; 3dly, the use of charcoal, too hard, not sufficiently burnt, and not used fresh.

These facts and observations well considered, will throw light upon the common processes for making steel, which I am about to detail.

Steel is made in 3 ways,

1st. It is made in Sweden and Germany from the crude iron. It cannot (as is said) be thus made from iron smelted with the coke of pitcoal. When the iron is carried in small pigs to the bloomery or refinery, it is melted on the hearth under charcoal. Grey cast iron is commonly used for the purpose. If it be much stirred and exposed to the blast in the bloomery, the superfluous carbon or charcoal will be burnt away; and by frequent heating and hammering it will become malleable bar iron: but if instead of being frequently stirred, the slag only is raked off as it forms, and the loop covered with charcoal, it will be a coarse kind of steel, much used on the continent of Europe for rough work, and cheap tools.

In order to obtain *Iron*, the fire place must be larger than for steel, and the tuyer must be inclined so as to direct the blast to the surface of the iron; the heat must be given gradually, and the iron frequently stirred, and raked, and kept in the state of a paste. But to make *Steel*, the heat must be given more suddenly, the iron must be placed on a bed of charcoal dust, and become fused, so as to sink below the Scoriæ or slag, and if these are removed, their place must be supplied by charcoal. In making iron at the refinery, the charcoal is burnt away; in making steel,

a more perfect union is produced between the charcoal and the iron. The process as described by Hazenfratz is as follows:

"The crude iron is reduced into thin plates, or leaves, when it is drawn from the smelting furnace. For this purpose a mould, or hemispherical cavity, is prepared before the furnace. It is formed of the scoriæ reduced into very fine powder, and wetted to make them adhere together.

The work is then opened with an iron bar, in order that the scoriæ may flow into the mould, and dissipate its moisture. These are in the next place taken out, and the metal itself is suffered to flow at first in a small stream, and afterwards more speedily. The aperture is enlarged in proportion as it flows out, and at last the scoriæ fall on the iron, and cover it in the mould. The furnace is then again closed, and the blast renewed. Water being thrown on the scoriæ which occupy the upper portion of the mould, they become fixed, and in this state are removed. A second portion of water is then thrown on the naked surface of the metal, which congeals to a small depth. The thin congealed plate is taken off, and a second aspersion of water is made, which affords a third plate. In this manner the process is continued, until as much of the metal is converted into plates as can be effected during the fluidity of the mass.

At some works the iron is melted in a particular furnace from the pig, for this purpose; but this second operation is evidently wasteful both of time and fuel.

The plates are intended to be made into either iron or steel.

In the process for making bar iron, the first operation consists in roasting the plates on a hearth, upon which they are arranged; a passage being formed with bricks, in order that the wind of the bellows may be directed from one extremity to the other. They are then covered with char-

coal, and urged strongly with the bellows. The plates by this roasting, which destroys the charcoal of the cast iron, begin to assume the qualities of bar iron, after which they are carried to the finery furnace. The body of this furnace is more capacious than that which is intended for steel. The iron is covered with charcoal and scoriæ, and the tuyere is inclined so that the blast strikes on the plates of metal. When the fusion is complete, the scoriæ are let out, the mass is frequently turned to expose it to the blast, and, lastly, the process being completed, the iron is conveyed to the hammer.

If the object be to form Steel, the furnace made use of is more contracted and deep. It is lined with pulverized charcoal, moistened and rendered solid by beating. The plates are disposed therein, and covered with scoriæ and charcoal. The position of the tuyere is nearly horizontal, in order that the stream of air may strike the fuel, and not the metal. When the metal begins to assume the solid state, the coal is taken off, the scoriæ are suffered to flow out, and scales and fragments of steel are driven by hammering into the soft mass.

The piece is afterwards melted a second time with the same precautions as before; and when the metal is thought to be sufficiently refined, the scoriæ are drawn off, and the mass is conveyed to the hammer to divide it into several pieces, which are to be separately forged out.

We see that all these operations are directed to the means of destroying the charcoal of the crude iron, when bar iron is wanted; but when steel is required to be made, the metal is not only preserved from the contact of the air, but the vessel is lined with charcoal, in order that, by its contact with the fused matter, it may supply any portion of that principle which may be wanting.

In the foregoing process there are two fusions of the metal. In the latter it is not only completed by the se-

cond fusion, but it is rendered more homogeneous. This method is excellent, and is perhaps the only means by which an exceedingly good steel can be had.

The other part of the process is worthy of much attention, namely, the reduction of the crude iron into plates. When bar iron is wanted, these plates roast with more facility on account of the great surface they present to the air. And when steel is wanted, they are more readily fused, and sink beneath the scoriæ, which prevents the charcoal of the iron from being consumed by the action of the air. On the contrary, they absorb what might have been wanting from the lining of the hearth or cavity, which is prepared in such a manner, as to support itself without being consumed, through the whole of the operation.

When the steel has congealed in the furnace, it is taken out and divided into several portions more or less considerable, which are carried to the hammer. Here a separation is made of such portions as are not reduced into steel, but iron, and which occupy the surface of the pieces. Each piece is drawn out into bars, which are reduced into other smaller bars of different dimensions, by separating the softest parts from those which are more hard.

For steel of a superior quality, several bars of the soft and hard kinds are united by welding and forging. The hardest are placed in the middle.

We have shown that in order to obtain steel from crude iron, it is necessary to have an iron abounding with coal; but there is an excess which is hurtful. The black crude iron, which contains too much coal, affords a steel so brittle as to be of no use. This kind of steel becomes fixed with more difficulty than good steel. When the workman perceives this symptom, he may prevent the bad effect by adding a certain quantity of old iron fragments, which deprives the too steely metal of its excess of coal, and, by incorporating with it, produces an uniform mass

of good steel. When the crude iron is of such a nature as to afford, brittle steel, it is usual to mix in the refining furnace a quantity of another kind of crude iron, which may modify its quality.

Though iron and steel are distinguishable by very striking qualities, there is, nevertheless, a point of contact at which they are confounded : the softest steel may be considered as a very hard iron, and, in fact, the several kinds of iron differ in hardness by the same principle which constitutes steel. They all retain a small portion of charcoal, which escapes the operation of refining. Those which contain the least are under like circumstances more flexible, soft, ductile, and susceptible of acquiring by the action of the hammer that fibrous form which constitutes what is called the grain of iron. Hence it is that different kinds of bar iron are sometimes obtained from the same crude iron, though the operation is apparently the same. It is sufficient for this effect that the inclination of the tuyer be changed. 2 Nich. Jour. qto. p. 66.

The next kind of steel, is 2dly, *Steel of cementation;* blistered steel.

Observations on Iron and Steel. By Joseph Collier. From the Transactions of the Manchester Society—with notes by T. C.

AFTER examining the works of different authors who have written on the subject of making iron and steel, I am persuaded that the accounts given by them of the necessary processes and operations are extremely imperfect. Chemists have examined and described the various compound minerals containing iron with great accuracy, but have been less attentive to their reduction. This observation more particularly applies to steel, of the making of which I have not seen any correct account. It is sin-

gular to observe how very imperfectly the cementation of iron has been described by men of great eminence in the science of chemistry. Fourcroy states the length of time necessary for the cementation of iron to be about twelve hours; but it is difficult to discover whether he alludes to cast or to bar steel: for he says, that short bars of iron are to be put into an earthen box with a cement, and closed up. Now steel is made from bars of iron of the usual length and thickness: but cast steel is made according to the process described by Fourcroy, with this essential difference—the operation is begun upon bar steel, and not bar iron.

Mr. Nicholson is equally unfortunate in the account given in his Chemical Dictionary. He says, that the usual time required for the cementation of iron is from 6 to 10 hours, and cautions us against continuing the cementation too long; whereas the operation, from the beginning to the end, requires 16 days at least. In other parts of the operation he is equally defective, confounding the making of bar with that of cast steel, and not fully describing either. In speaking of the uses of steel, or rather of what constitutes its superiority, Mr. Nicholson is also deficient. He observes that "its most useful and advantageous property is that of becoming extremely hard when plunged into water." He has here forgotten every thing respecting the temper and tempering of steel instruments, of which, however, he takes some notice in the same page. "Plunging into water" requires a little explanation: for if very hot steel be immersed in cold water without great caution, it will crack, nay sometimes break to pieces. It is however necessary to be done, in order to prevent the steel from growing soft, and returning to the state of malleable iron; for, were it permitted to cool in the open air, the carbon which it holds in com-

bination would be dissipated*. I shall at present confine my remarks to the operations performed on iron in Sheffield and its neighbourhood, from whence various communications have been transmitted to me by resident friends, and where I have myself seen the operations repeatedly performed. The iron made in that part of Yorkshire is procured from ores found in the neighbourhood, which are of the argillaceous kind, but intermixed with a large proportion of foreign matter. These, however, are frequently combined with richer ores from Cumberland and other places. The ore is first roasted with cinders for three days in the open air, in order to expel the sulphureous or arsenical parts, and afterwards taken to the furnaces, some of which are constructed so that their internal cavity has the form of two four-sided pyramids† joined base to base; but those most commonly used are of a conical form, from forty to fifty feet high. The furnace being previously heated in various proportions according to the nature of the ore, is charged at the top with coal-cinder and limestone. The limestone acts as a flux, at the same time that it supplies a sufficient quantity of earthy matter, to be converted into scoriæ, which are necessary to defend the reduced metal from calcination, when it comes near the lower part of the furnace. The fire is lighted at the bottom; and the heat is excited by means of two pair of large bellows‡ blowing alternately. The quantity of air generally thrown into the furnace is from 1000 to 1200 square feet in a minute.¶ The air passes through a pipe, the diameter of which is from two inches

* It is the opinion of some metallurgists, that a partial abstraction of oxygen takes place, by plunging hot metal into cold water.

† Rather two inverted cones, of which the base of the larger rests upon the base of the smaller.

‡ These are now discarded and large cast iron cylinders substituted in their stead.

¶ From 1500 to 1800 out of a pipe of 2½ or 3 inch bore.

and a quarter to two and three quarters wide. The compression of air which is necessary is equal to a column of water four feet and a half high.* The ore melts as it passes through the fire, and is collected at the bottom, where it is maintained in a liquid state. The slag, which falls down with the fused metal, is let off by means of an opening in the side of the furnace, at the discretion of the workmen. When a sufficient quantity of regulus, or imperfectly reduced metal, is accumulated at the bottom of the furnace (which usually happens every eight hours,) it is let off into moulds, to form it for the purposes intended, such as cannon or pig iron.—Crude iron is distinguished into white, black,† and grey. The white is the least reduced, and more brittle than the other two; the black is that with which a large quantity of fuel has been used; and the grey is that which has been reduced with a sufficient quantity of fuel, of which it contains a part in solution. The operation of refining crude iron consists in burning the combustible matter which it holds in solution; at the same time that the remaining iron is more perfectly reduced, and acquires a fibrous texture. For this purpose, the pigs of cast iron are taken to the forge, where they are first put into what is called the refinery; which is an open charcoal fire, urged by a pair of bellows, worked by water or a steam-engine; but the compression of air in the refinery ought to be less than that in the blast-furnace. After the metal is melted, it is let out of the fire by the workmen to discharge the scoriæ, and then returned and subjected to the blast as before. This operation is sometimes repeated two or three times before any appearance of malleability (or what the workmen call coming into nature) takes place; this they know by the metal's first assuming a granular appearance, the particles appearing to repel each other, or

* This ought to be 6 inches of mercury, or 6 feet of water.

† Mottled.

at least to have no signs of attraction. Soon afterwards they begin to adhere, the attraction increases very rapidly, and it is with great difficulty that the whole is prevented from running into one mass, which it is desirable to avoid, it being more convenient to stamp small pieces into thin cakes: this is done by putting the iron immediately under the forge hammer, and beating it into pieces about an inch thick, which easily break from the rest during the operation. These small pieces are then collected and piled to the height of about ten inches upon circular stones, which are an inch thick and nine inches in diameter. They are afterwards put into a furnace, in which the fire is reverberated upon them until they are in a semi-fluid state. The workmen then take one out of the furnace, and draw it into a bar under the hammer; which being finished, they apply the bar to another of the piles of semi-fluid metal, to which it quickly cements, is taken again to the hammer, the bar first drawn serving as a handle, and drawn down as before. The imperfections in the bars are remedied by putting them into another fire called the chafery, and again subjecting them to the action of the forge-hammer.

The above method is now most in use, and is called *flourishing;* but the iron made by this process is in no respect superior to that which I am going to describe. It is however not so expensive, and requires less labour.

The process for refining crude iron, which was most common previous to the introduction of flourishing, is as follows:

The pigs of cast iron are put into the refinery, as above, where they remain until they have acquired a consistence resembling paste, which happens in about two hours and a half. The iron is then taken out of the refinery, and laid upon a cast iron plate on the floor, and beaten by the workmen with hand-hammers, to knock off the cinders and other extraneous matters which adhere to the metal. It is

afterwards taken to the forge-hammer, and beaten first gently, till it has obtained a little tenacity; then the middle part of the piece is drawn into a bar about half an inch thick, three inches broad, and four feet long, leaving at each end a thick square lump of imperfect iron. In this form it is called Ancony. It is now taken to the fire called the chafery, made of common coal; after which the two ends are drawn out into the form of the middle, and the operation is finished.

There is also a third method of rendering crude iron malleable, which, I think, promises to be abundantly more advantageous than either of the two former, as it will dispense both with the refinery and chafery; and nothing more will be necessary than a reverberating furnace, and a furnace to give the metal a malleable heat, about the middle of the operation. The large forge-hammer will also fall into disrepute, but in its place must be substituted metal rollers of different capacities, which like the forge-hammer, must be worked either by a water-wheel or a steam-engine.

It is by the operation of the forge-hammer or metal rollers, that the iron is deprived of the remaining portion of impurity, and acquires a fibrous texture.

The iron made by the three foregoing processes is equally valuable, for by any of them the metal is rendered pure; but after those different operations are finished, it is the opinion of many of the most judicious workers in iron, that laying it in a damp place for some time improves its quality; and to this alone some attribute the superiority of foreign iron, more time elapsing between making and using the metal. To the latter part of this opinion I can by no means accede, as it is well known that the Swedish* ores contain much less hetero-

* Steel is commonly made of Swedish iron. Oregrund iron as it is called, but that is only the mart: the ore is from Dannemora.

geneous matter than ours, and are generally much richer, as they usually yield about 70 *per quintal* of pure iron, whereas the average of ours is not more than 30 or 40*: add to this, that the Swedish ores are smelted in wood fires, which gives the iron an additional superiority.

Iron instruments are case-hardened by heating them in a cinder or charcoal fire; but if the first be used, a quantity of old leather or bones must be burnt in the fire, to supply the metal with carbon. The fire must be urged by a pair of bellows to a sufficient degree of heat, and the whole operation is usually completed in an hour.

The process for case-hardening iron is in fact the same as for converting iron into steel, but not continued so long, as the surface only of the article is to be impregnated with carbon. Some attempts have been made to give cast-iron, by case-hardening, the texture and ductility of steel; but they have not been very successful. Table and pen-knife blades have been made of it; and, when ground, have had a pretty good appearance; but the edges are not firm, and they soon loose their polish. Common table knives are frequently made of this metal. The cementation of iron converts it into steel, a substance intermediate between crude and malleable iron.

The furnaces for making steel are conical buildings; about the middle of which are two troughs of brick or fire-stone, which will hold about four tons of iron in the bar. At the bottom is a long grate for fire. The steel furnace, however, is not well adapted for description. I shall therefore avail myself of an accurate drawing, which was communicated to me by a gentleman conversant with the manufacture, and which is copied in the plate. A layer of charcoal-dust is put upon the bottom of the trough,

* The iron made from the ore found in the neighbourhood of Sheffield, contains a great deal of phosphate of iron or siderite, which renders the metal brittle when cold. I doubt this. T. C.

and upon that a layer of bar iron, and so on alternately until the trough is full. It is then covered over with clay to keep out the air*; which, if admitted, would effectually prevent the cementation. When the fire is put into the grate, the heat passes round by means of flues, made at intervals, by the sides of the trough. The fire is continued until the conversion is complete, which generally happens in about eight or ten days. There is a hole in the side, by which the workmen draw out a bar occasionally, to see how far the transmutation has proceeded. This they determine by the blisters upon the surface of the bars.

If they be not sufficiently changed, the hole is again closed carefully, to exclude the air; but if, on the contrary, the change be complete, the fire is extinguished, and the steel is left to cool for a few days more, when the process for making blistered steel is finished. For small wares, the bars are drawn, under the tilt hammer, to about half an inch broad and three-sixteenths of an inch thick. The change wrought on blistered steel by the tilt hammer, is nearly similar to that effected on iron from the refinery by the forge hammer. It is made of a more firm texture, and drawn into convenient forms for use. German steel is made by breaking the bars of blistered steel into small pieces, and then putting a number of them into a furnace; after which they are welded together and drawn to about eighteen inches long; then doubled and welded again, and finally drawn to the size and shape required for use. This is also called shear steel, and is superior in quality to the common tilted steel. Cast steel is also made from the common blistered steel. The bars are broken, and

* Or with 4 inches deep of moist sand. Indeed the clay should be covered with a layer of sand, to fill up the cracks made by the heat. 100lb. of iron gains half a pound by being converted into blistered steel. T. C.

put into large crucibles with a flux.* The crucible is then closed up with a lid of the same ware, and placed in a wind furnace. By the introduction of a greater or smaller quantity of flux, the metal is made harder or softer.

When the fusion is complete, the metal is cast into ingots, and then called ingot steel; and that which afterwards undergoes the operation of tilting, is called tilted cast steel. The cast steel is the most valuable, as its texture is the most compact, and it admits of the finest polish. Sir T. Frankland has communicated a process, in the Transactions of the Royal Society,† for welding cast steel and malleable iron together; which, he says, is done by giving the iron a malleable, and the steel a white heat; but, from the experiments which have been made at my request, it appears, that it is only soft cast steel, little better than common steel, that will weld to iron: pure steel will not; for, at the heat described by Sir T. the best cast steel either melts, or will not bear the hammer. It may here be observed, as was mentioned before, that steel is an intermediate state between crude and malleable iron, except in the circumstance of its reduction being complete; for, according to the experiments of Reaumur and Bergman, steel contains more hydrogen gas than cast iron, but less than malleable iron;—less plumbago‡ than the first, but more than the latter;—an equal portion of manganese with each;—less siliceous earth than either;—more iron than the first, but less than the second. Its fusibility is likewise intermediate between the bar iron and the crude. When steel has been gradually

* Phil. Trans. 1795.

† Limestone and bottle glass pounded. The limestone is decomposed, and the steel abstracts an additional dose of carbon, from the carbonic acid of the limestone, as is supposed: but I suspect a small quantity of lamp-black is added. T. C.

‡ Rather carbon. Plumbago or black lead is carbon united to a very small proportion of iron. T. C.

cooled from a state of ignition, it is malleable and soft, like bar iron; but when ignited and plunged into cold water, it is the hardness and brittleness of crude iron. From the foregoing facts we are justified in drawing the same conclusions with Reaumur and Bergman, but which have been more perfectly explained by Vandermonde, Berthollet, and Monge, that crude iron is a regulus, the reduction of which is not complete; and which consequently will differ according as it approaches more or less to the metallic state. Forged iron, when previously well refined, is the purest metal; for it is then the most malleable and the most ductile, its power of welding is the greatest, and it acquires the magnetic quality soonest. Steel consists of iron perfectly reduced and combined with charcoal; and the various differences in blistered steel, made of the same metal, consist in the greater or less proportion of charcoal imbibed. Iron gains, by being converted into steel, about $\frac{1}{180}$ part of is weight. In order to harden steel, it must be put into a clean charcoal, coal or cinder fire, blown to a sufficient degree of heat by bellows. The workmen say, that neither iron nor steel will harden properly without a blast. When the fire is sufficiently hot, the instrument intended to be hardened must be put in, and a gradual blast from the bellows continued until the metal has acquired a regular red heat: it is then to be carefully quenched in cold water. If the steel be too hot when immersed in water, the grain will be of a rough and coarse texture; but if a proper degree of heat, it will be perfectly fine. Saws and some other articles are quenched in oil. Steel is tempered by again subjecting it to the action of the fire. The instrument to be tempered we will suppose to be a razor made of cast steel. First rub it upon a grit stone until it is bright, then put the back upon the fire, and in a short time the edge will become of a light straw colour, whilst the back is blue.

The straw colour denotes a proper temper, either for a razor, graver, or pen-knife. Spring knives require a dark brown; scissars a light brown or straw colour; forks or table-knives a blue. The blue colour marks the proper temper for swords, watch-springs, or any thing requiring elasticity. The springs for pen-knives are covered over with oil before they are exposed to the fire to temper.

Explanation of the Plate. Fig. 1. is a plan of the furnace, and fig. 2. is a section of it taken at the line AB. The plan is taken at the line CD. The same parts of the furnace are marked with the same letters in the plan and in the section. EE are the pots or troughs into which the bars of iron are laid to be converted. F is the fire-place; P the fire-bars; and R the ash-pit. GG, &c. are the flues. HH is an arch, the inside of the bottom of which corresponds with the line IIII, fig. 1. and the top of it is made in the form of a dome, having a hole in the centre at K, fig. 2. LL, &c. are six chimneys. MM. is a dome similar to that of a glass-house, covering the whole. At N there is an arched opening, at which the materials are taken in and out of the furnace, and which is closely built up when the furnace is charged. At OO there are holes in each pot, through which the ends of three or four of the bars are made to project quite out of the furnace. These are for the purpose of being drawn out occasionally to see if the iron be sufficiently converted.

The pots are made of fire-tiles or fire-stone. The bottoms of them are made of two courses, each course being about the thickness of the single course which forms the outsides of the pots. The insides of the pots are of one course, about double the thickness of the outside. The partitions of the flues are made of fire-brick, which are of different thicknesses, as represented in the plan, and by dotted lines in the bottom of the pots. These are for sup-

Steel Furnace.

Fig. 2.

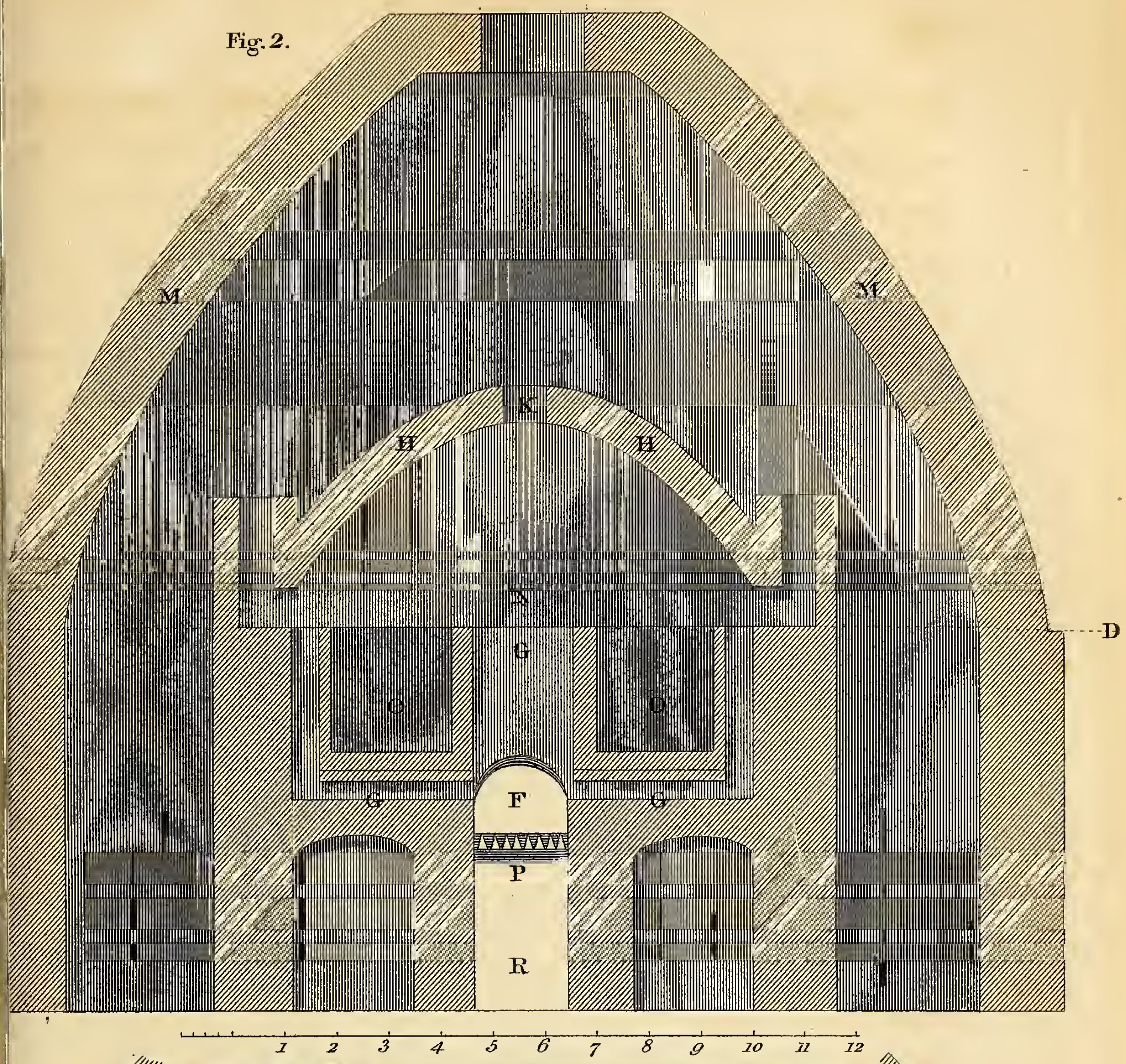
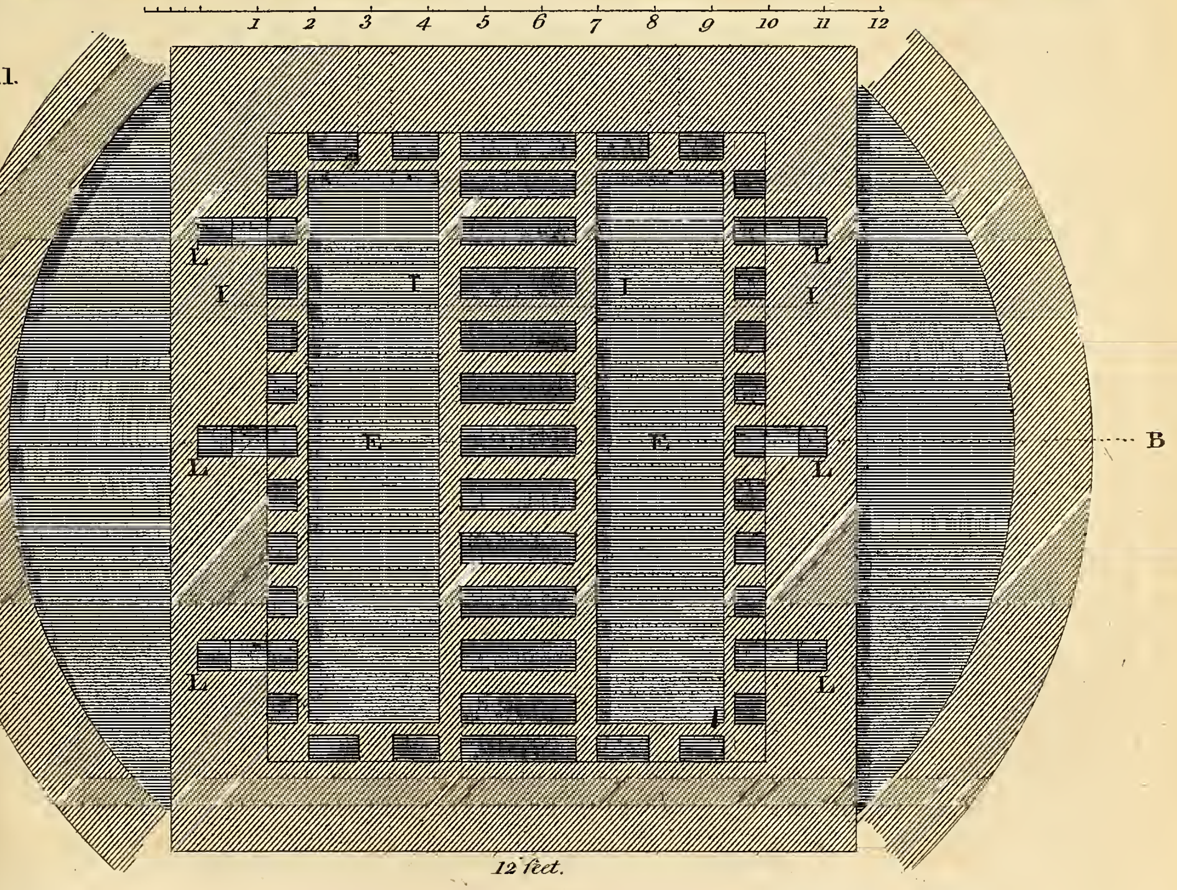


Fig. 1.



12 feet.

C. Tiebout sc.

porting the sides and bottoms of the pots, and for directing the flame equally round them. The great object is to communicate to the whole an equal degree of heat in every part. The fuel is put in at each end of the fire-place, and the fire is made the whole length of the pots, and kept up as equally as possible."

On this paper of Collier's it may be remarked, that the bars are often put into iron as well as brick or earthen cases, and indeed in England generally so—that although the heating and cooling may occupy altogether a dozen days, it does not require more than a dozen hours of *white* heat, to convert into good blistered steel, bar iron the 8th of an inch thick—that steel of cementation, blistered or German bar steel, should be made of the very best, and best worked iron that can be procured; generally of Swedish iron, the whole of which used to be bought up by 2 or 3 houses in England. If not well hammered in its state of iron, it will shew the want of uniformity in its texture, much more as steel——Cast steel is always made originally from bar steel, or steel of cementation——equal proportions of limestone and cinders, is far too much of limestone: one part of limestone to 3 or 4 of cinders is more common; and the English rich Cumberland ore, worked with wood charcoal, requires no more than one twentieth of limestone—there is hardly any such thing in use at an English blast furnace as bellows; they are supplied with air either from cast iron drums or cylinders worked with the power of water or steam; or by a water blast; and the air is condensed so as to support a column of 6 inches of mercury; by which compression from 15 to 1800 cubic inches of air will pass through the discharging pipe of 3 inches wide in a minute——Mr. Collier has not noticed the common process of puddling introduced by Mr. Cort, which has succeeded in practice; and

of which Dr. Beddoes has given a detailed account in the 5th volume of the Manchester Transactions.

Process of making Steel at Newcastle, in England. 1 Jars Voyages. Metallurgiques, 221.

"There are several steel furnaces at Newcastle of different sizes, but similar proportions. The mason work of the cementing furnace, is an oblong square. A fire-place with bars passes the whole length. This grate, 20 inches wide, is nearly on a level with the ground; the ash-hole is underneath. Sixteen inches above the grate on each side are placed the cases wherein the bars are arranged that are to be converted into steel. For this purpose ten flues are worked into the wall of those crucibles or cases on each side of their length; they are of fire-brick and cemented with loam well beaten and worked. The inside dimensions of the cases are 10 1-2 feet long, 2 feet 4 inches wide, and 2 feet 6 inches deep. The flame circulates all round the cases, whose sides are supported by walls that enable them to sustain the weight of iron within. An arch is thrown over the cases and fire-place in order that the flame may reverberate on the top of the cases. The flame and smoke passes out at eight openings. The whole communicates with one common chimney of a conical form. The cases are of hewn fire-stone.

No iron is used for the purpose of steel but Swedish iron.

The iron bars are cut to the length of the inside of the cases: they are of different breadths, from an inch and a half to two inches and an half, and from four to seven lines thick, (12 lines make an inch.) Each case can hold ten tons of iron of 21 cwt. of 112 lbs. each to the ton.

The only substance used is charcoal dust:* neither oil nor salt. The bottom of the cases are covered with charcoal dust sifted through a coarse sieve, and slightly

* I believe animal substances are frequently added. T. C.

moistened, about an inch thick: in this the bars are laid side by side with about 1-4th inch of charcoal dust between each bar. This layer is covered with half an inch of charcoal dust, and this again with a layer of bars. The last layer is covered with 2 inches of charcoal, and this with a coating of clay, or of moistened sand. The sand is raised up high in the middle where it is about 10 inches thick. If the charcoal were exposed to the air, it would burn away. The walls at the breadth of the cases are now built up, leaving only a hole in the middle of each, stopped up with loose brick, big enough to take out a trial bar. The mouth of the fire-place at each end is also built up so as to leave only an opening of about 10 inches by 8 to feed the grate with fuel and stir the fire; this hole is shut by an iron plate as a door; so that the air ascends up the ash-hole and through the bars to maintain the fire. The fire is generally lighted on Monday evening, and is kept up as hot as can be from thence till Saturday night, which is about the time that ten tons of iron takes to be converted into steel. If there be more than ten tons, the fire is put in on Sunday night. Toward the latter end of the time, the trial bar from the middle of the cases at each end is examined. When the process is over, the fire is drawn, by removing the moveable bars between the fixt bars of the grate, so as that the fuel tumbles into the ash-hole. The whole then is left to cool, which takes near a week more. They calculate to burn from 16 to 18 fodder of coal, each fodder weighing 16 cwt. and being worth four shillings sterling, or from 250 to 290 cwt. of coal. They say the iron neither gains or loses in weight by the operation. This is *blistered* steel, and sold (the volume bears date 1774) at 26 to 28 shillings the cwt.

These flat bars of steel, when cold, are drawn into square bars, of about 3-4ths of an inch thick, which are

suffered to cool in the air, without being plunged in water. This greatly improves the appearance of the grain, which before it has undergone the tilt hammer, has a large grained fracture more like brittle iron than steel. This is *common* steel, used for files, saws, scissars, knives, &c. It fetches from 30 to 32 shillings the cwt. The ends of each bar, where the steel is usually not of so good quality as the rest, are cut off, and these are forged together into bars and made up in bundles or faggots under the denomination of *soft* steel, which answers for plough-irons, the edges of spades, &c. and common blacksmiths' work.

To make (or rather to imitate) *German* steel, they take a truss of ten or a dozen bars of blistered steel, they heat them together, covering them with dry clay in powder, which seems to concentrate the heat, and prevent the action of the air; the bars are then taken out, and well worked together under the hammer, and then drawn out into bars of a convenient size. This produces a perfect imitation of the real German steel in appearance and quality, and is in fact the same process as is used for the best steel in Styria. The heat is given by coke; but it would perhaps be better with charcoal; indeed some manufacturers take the blistered steel, heat it as above with charcoal, draw it out into German steel, then cement it over again with charcoal dust as is done to iron in the first instance; they then again draw it out into bars.

Other manufacturers, take pieces of old files, and refuse steel of all kinds, and melt them in a crucible with a flux, of which they make a secret." Thus far Jars's account.

(To be continued.)

On the Comparative Height of the Mountains of the Earth, the Moon, and Venus.*

SCHROETER, the learned astronomer of Lilienthal, who has several excellent telescopes by Herschel, published some time ago a work on the height of the lunar mountains, as compared with those of the earth; and lately he has published a new work on the height of the mountains of Venus. Faujas, who not long ago undertook a journey into Germany, of the utmost importance to the sciences, brought back with him these two works of Schroeter. We there see the manner in which that indefatigable astronomer makes his observations. It is by the projection of the shadows formed by these mountains when they begin to appear on their horizon in regard to us, or when they are about to disappear below the horizon. He distinguishes the mountains into different orders.

The plate in Schroeter's work consisted only of outline, and he expressed the diameter of the three globes merely by straight lines. The annexed delineation (See Plate) was drawn by Alexander Faujas, the son, who to military talents unites a stong attachment to the sciences. He has rendered the height of the mountains more just, and, from his drawing the respective magnitude of the three globes can be better estimated. It is here seen that the moon, which is about forty-nine times smaller than the earth, has mountains more than 4000 toises in height†; while that of Chimboraco, one of the Andes in South America, the highest mountain of our globe, is little more than 3000. Venus, which is less than the earth by a ninth has mountains 23,000 toises in height. It must here be remarked, that the highest mountains on these three globes appear all to be volcanic.

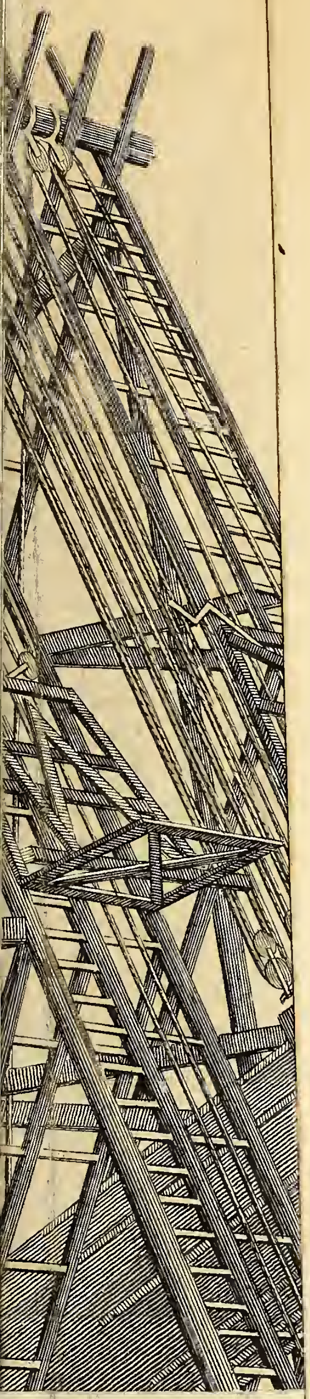
* From the Journal de Physique, Prairial, An. 7.

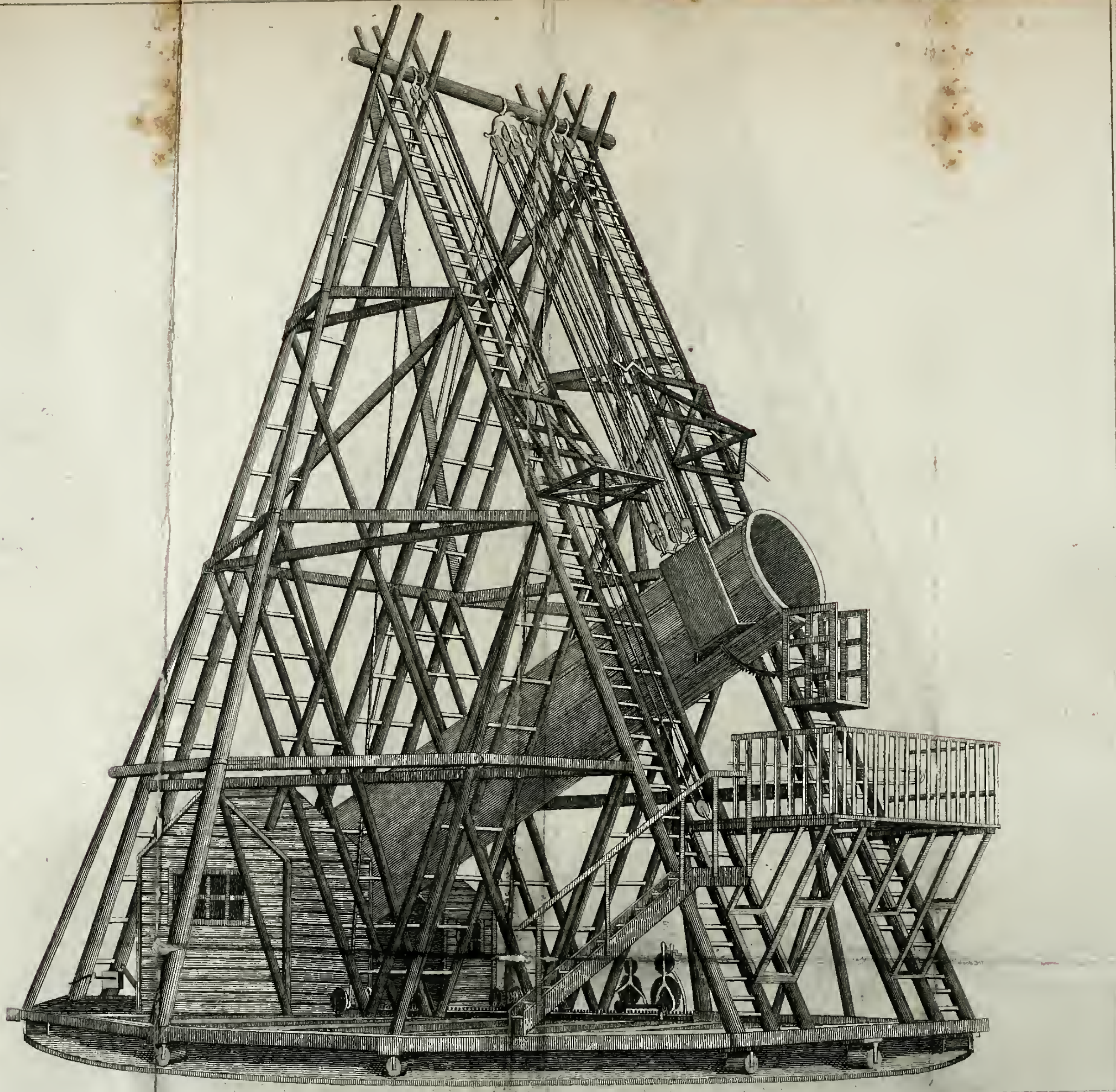
† The French toise is to the English fathom as 1 to 1·0664.

Description of Herschell's Forty-foot Reflecting Telescope, Accompanied with an Engraving.

THE Telescope is placed in a situation due north and south, and the plate delineates the whole apparatus as seen by a person placed at a convenient distance from it towards the south-west. From this view the structure is sufficiently understood; and, with very little attention, the mode of pointing this immense body to any part of the heavens will be clearly seen. We shall treat of the chief parts in their order; and first, of the tube itself.

The tube is made of rolled or sheet iron joined together without rivets, by a similar seaming to that which is used for iron funnels for stoves; the thickness of the sheets is somewhat less than a 36th part of an inch, or it may be found more accurately by taking a square foot of it at the weight of fourteen pounds. Great care was taken in so joining the plates of which the tube is composed together, that the cylindrical form should be secured, and then the whole was coated over three or four times with paint, inside and outside, to secure it against the damp. The tube was formed at a short distance from its present place, and removed with great ease by twenty-four men, divided into six sets; so that two men on each side with a pole of five feet long in their hands, to which was affixed a piece of coarse cloth, seven feet long, going under the tube, and joined to a pole of five feet long, in the hands of two other men, assisted in carrying the tube. The length of the tube is 39 feet 4 inches, the diameter 4 feet 10 inches; and, upon a moderate computation, it is supposed that a wooden tube for the same purpose would have exceeded this in weight by at least 3000 pounds. The length of the iron plate forming the tube, and composed of smaller ones 3 feet 10 inches long and 23 1-2 inches broad, is nearly 40 feet, and the breadth 15 feet 4 inches.





VIEW OF HERSCHELL'S FORTY-FOOT REFLECTING TELESCOPE.

The great mirror which, by proper methods, was brought to the lower part of the tube, is made of metal, 49 1-2 inches in diameter; but the concave part, or polished surface, is only 48 inches in diameter. Its thickness is 3 1-2 inches; and, when it came from the cast, its weight was 2118 pounds, of which a small quantity must have been lost in polishing. An iron ring, 49 1-2 inches in diameter, within 4 inches broad, and 1 1-8 inch thick, with three strong handles to it, goes round the mirror, and a flat cover of tin is made to correspond to this ring that the mirror may be preserved from damp; and, by an easy contrivance, it is taken off and fixed on at pleasure.

At the upper end, the tube is open, and directed to the part of the heavens intended for observation, to which the observer's back is turned, and, he standing on the foot-board visible in the plate, looks down the tube, and perceives the object by rays reflected from the great mirror, through the eye-glass at the opening of the tube. Near the place of the eye-glass is the end of a tin pipe, into which a mouth-piece may be placed; so that, during an observation, a person may direct his voice into this pipe, whilst his eye is at the glass. This pipe is 1 1-2 inch in diameter, runs down to the bottom of the tube, where it goes into a turning joint, thence into a drawing tube, and out of this into another turning joint, from which it proceeds by a set of sliding tubes towards the front of the foundation timber. The use of this tube is to convey the voice of the observer to his assistants; for at the last place it divides itself into two branches, one going into the observatory, the other into the workman's room, ascending in both places through the floor, and being terminated in the usual shape of speaking-trumpets. Though the voice passes in this manner through a tube with many inflections, and not less than 115 feet, it requires very little exertion to be well understood.

To direct so immense a body to any part of the heavens at pleasure, much ingenuity, and many mechanical contrivances are evidently necessary. The whole apparatus rests upon rollers, and care was previously taken of the foundation in the ground. This consists of concentrical circular brick walls, the outermost 42 feet, the innermost 21 in diameter; 2 feet 6 inches deep under ground, 2 feet 3 inches broad at the bottom, and 1 foot 2 inches at the top, capped with paving-stones, about 3 inches thick, and 12 3-4 inches broad. In the centre is a large post of oak, framed together with braces under ground, and walled fast with brick-work, to make it steady. Round this centre, the whole frame is moved horizontally, by means of 20 rollers, 12 upon the outer and 8 upon the inner wall.

The vertical motion is given to the telescope by means of ropes and pullies, as seen in the plate, passing over the main-beam, supported by the ladders. These ladders are in length forty-nine feet two inches; and there is a moveable gallery with twenty-four rollers to ease its motion. The small stair-case visible in the plate, is intended for persons who wish to ascend into the gallery, without being obliged to go up the ladder. The ease with which the horizontal and vertical motions may be communicated to the tube will be best conceived from a remark of HERSCHELL, that, in the year 1789, he several times observed Saturn two or three hours before and after its meridian passage, with one single person to continue at his directions the necessary horizontal and vertical motions.

Upon the platform are visible two rooms, the one called the Observatory, eight feet five inches, by five feet five inches, the other called the Working-room six feet six inches by four feet five inches. To persons in these rooms, as has been above remarked, the observer can give his directions by means of the speaking-pipes; and in

the rooms may be placed things, commonly used in Observatories.

From a view of the plate and a description thus given of it, our readers, we presume, will form a competent idea of an instrument, which, with proper eye-glasses, magnifies above six thousand times, and is the largest that has ever been made. Astronomers in different parts of the world may be discouraged from continuing their observations, when it should seem, that their discoveries must be anticipated by HERSCHELL; but though he has so much the advantage, much is left to their labour and industry. It did not require a telescope of this magnitude to observe the object which was first discovered to be a planet by this Astronomer, for it had been seen and taken for a fixed star by many persons in the two last centuries. And the double ring of Saturn, which has, indeed, been so beautifully observed through HERSCHELL'S magnifier, had been already described by Cassini in his Memoirs. Such of our readers as wish for a more accurate account of this instrument, will find it in the Transactions of the Royal Society for 1795, second part; in which there are eighteen plates and sixty-three pages of letter-press, to give an ample detail of every circumstance relating to joiners' work, carpenters' work, smiths' work, &c. which has attended the formation and erection of this instrument. It was completed on August 28th, 1789, on which day the sixth satellite of Saturn was discovered.

EVAPORATION IN VACUO.

Some account of experiments in France, in prosecution of Professor Leslie's discovery of the method of congelation by means of a vacuum.

It will be proper to give some previous account of what has already been done by professor Leslie, before I introduce the following paper from the Journal de Physique, of October 1812.

The effects of evaporation in producing cold have long been known. Dr. Cullen and Dr. Bryan Higgins applied ether for this purpose by moistening slowly the bulb of a thermometer. Higgins, by this method, reduced the mercury to 40 of Fahrenheit. Cavallo invented a very simple and ingenious apparatus for freezing by means of ether.

In 1795 Mr. Oliver Evans suggested the possibility of freezing water by means of evaporation of ether *in vacuo*, but he does not appear actually to have made the experiment, though he has suggested the means.

In 1810 or very early in 1811, Professor Leslie, in making some experiments in relation of air and moisture, succeeded in freezing water in vacuo, by causing the vapour raised from the water to be absorbed by strong sulphuric acid, the water being contained in a small shallow dish about two inches above the surface of the acid: and in the beginning of 1812 by means of an apparatus connected with an excellent air pump, he succeeded in freezing mercury, by moistening the bulb of a thermometer with water, repeatedly, until the effect was produced. Soon after his first experiment, he proposed to apply the principle in the large way to the production of ice, the concentration of juices, the drying of gunpowder, &c.

In 1811 M. M. Clement and Desormes, in France, proposed also the application of the same principle to the

same purposes: a brief account of their memoir from Cuvier's report of the discoveries of the year 1811, I published in the Port Folio, for September 1812.

The following paper presents us with a new and ingenious method of producing similar effects, by means more adapted to common use. I have translated it for this work. T. C.

From the Journal de Physique, of October 1812.

Notice of the effects of evaporation in vacuo, and on the means of producing a vacuum without employing an air pump, by M. Honorè Flaugergues.

The academy of sciences, belles lettres and arts at Lyons, proposed in 1811 as the subject of a prize "The developement of the theory of the congelation of water, by the vacuum of an air pump, and of the phenomena accompanying this experiment: and also to determine its application to economical uses; whether for the purpose of obtaining ice at all seasons and in all places, or of desiccating viands, and milk, and inspissating the juices of fruits."

One of the silver medals was decreed by the society to M. Configliachi, professor of Philosophy at Pavia, for a memoir presented by that gentleman, which contained a luminous theory and beautiful experiments. It is sufficient to mention here, that the learned Professor had contrived by means of an excellent air pump to make a vacuum so perfect, that the simple congelation of water therein, produced a degree of cold nearly approaching to that, which with the assistance of mercury had equalled the degree of congelation of mercury; and at length by employing ether instead of water, the mercury became solid in the midst of summer, and the degree of cold reached to 41 below Zero of Reaumur's Thermometer.

The society also did me the honour of presenting me

with a silver medal for some economical views of this subject that I submitted to their consideration. A good air pump, is an instrument too expensive and too scarce for common use; and it requires also much attention when used. Nor can it be applied to operations in the large way. I have therefore endeavoured to supply its place, by a method sufficiently plain and simple to be within the reach of every body, *by exhausting a vessel of air by means of steam, and then causing that steam to be absorbed by sulphuric acid, by dry pot ash, or by quick lime, and preventing the external air from entering the exhausted vessel.* It is evident that such a vessel ought to remain empty of air; and that the vacuum will be more perfect in proportion as the estimate of the air has been more exact. But I have found by means of several experiments made with the utmost care, that by causing a small quantity of water to boil in a vessel, the air may be expelled and a vacuum formed so nearly perfect, that the remaining air would not occupy a space greater than the 4645th part of the capacity of the vessel: an approximation which no air pump has yet equalled. Few air pumps even under favorable circumstances are able so to rarify the air, as to lower the mercury of a manometer half a line below its level; while in air rarified to the degree above mentioned, the mercury would stand at 0,073 only above its level. (A manometer or manoscope, is an instrument contrived to measure the *density* of the air: the barometer measures only the *weight* of the air.)

For the purpose of repeating the well known experiment of Mr. Leslie, on the congelation of water in vacuo, by the means I propose, we may proceed thus. Take a bell glass or any glass receiver; drive out the air by boiling in it when turned upside down, a small quantity of water, or by placing it on a trough full of boiling water, or by introducing under it or withinside, any body brought

to the state of incandescence whereon you may project a few drops of water: so soon as it is completely filled with steam, turn it quickly with its mouth downward upon a plate or dish whereon you have previously placed two capsules, the one containing concentrated sulphuric acid, the other water. There should be a border of wax softened with turpentine into which the edge of the inverted bell glass should be pressed, to exclude the access of external air; and the wax should also be pressed close to the edge of the glass. The oil of vitriol will soon absorb the vapour, and if the experiment has been neatly conducted, the other capsule containing water, will exhibit the paradoxical appearance of ice formed by the means of boiling water.

The advantage of being thus able to procure ice at all seasons and in all situations, may be considered as more curious than useful. But a method of operating in the large way upon the same principle, without the aid of an air pump, and by means of which meat, fish, milk, &c. may be dried, the juices of fruits and saline solutions concentrated so as to serve the purposes of general conveniance, is what I mean to propose.

I have discovered that steam may be raised by throwing water on ignited substances, and that steam may be absorbed by substances proper for the purpose in large boxes or chambers. The vacuum thus produced will remain a considerable time, provided the boxes are exactly jointed, made of compact wood, and covered on the outside with three or four coats of fat varnish, or amber varnish. Nor will the pressure of the atmosphere pass through a stone wall, if made of vitrifiable stones (quartzose) or of basalt, cemented by mastic: (that is I presume not varnish made of mastic, but any resinous cement.) Hence for the purpose of using this new method of desiccation, *cold stoves* may be employed, where the subjects will

be dried more readily than by means of fire, and will not experience those changes which the action of heat never fails to produce. Moreover, this method of evaporating requires hardly any expence, for the sulphuric acid or the potash made use of, need only be exposed to fire to drive off the moisture they have imbibed, without any loss of the articles themselves.

This new method of evaporating in vacuo, may also be applied with success to the distillation of spirituous liquors, as I have satisfied myself by some trials made with this view. Having by means above described driven out all the air contained in the head of an Alembic to the beek of which I had luted a matrass, I placed the head upon a plate whereon there were also placed a capsule full of sulphuric acid, and another of weak spirit of wine. I carefully luted the junctures, the spirit of wine was raised in vapour, the watery part or phlegm was absorbed by the acid of vitriol, and the rectified spirit was distilled into the matrass by the sole heat of the atmosphere, which was at that time from 18 to 20. (72 to 77 of Fahrenheit if Reaumur's scale be meant, and 64 to 68 of Fahrenheit if Celsius's or the Centyrade thermometer be meant. I am in doubt which is referred to here.)

This method of distilling by evaporation without fire, seems to me too much neglected at a time when the scarcity of fuel renders it desirable to diminish the consumption as much as possible. (Mr. Watt while making experiments on steam during the invention of the improvements made on the steam engine by himself, made also many experiments to distill in vacuo, but without success in a large way. T. C.)

NUTRITION OF VEGETABLES.

Of all the investigations hitherto published on the Theory of Vegetation, I know of none that furnishes results so curious, or so important to Vegetable Physiology, as the following paper of M. Bracannot " On the Assimilating Power of Vegetables :" abridged from the Annales de Chemie, vol. lxi. p. 187. *Feb.* 1807. *The experiments must be varied and repeated, before they can be considered as conclusive. But should they be found true, they will go a great way to induce us to believe, that potass, and even carbon, are compounds, and products of vegetable organization formed out of oxygen, hydrogen and light. See* 18 *Nich. Jour.* 15.

PHYTOLOGISTS for a long time imagined, that vegetables were nourished by certain juices, which they extracted ready formed from the earth. Van Helmont in great measure refuted this by his celebrated experiment. In a box containing 100 lbs. of earth, and covered with lead, he planted a willow, weighing 50 lbs. This he watered with distilled water, and in five years it had acquired an addition to its weight of 119 lbs. 3 oz. without any perceptible diminution of the earth. The experiments of Boyle with earth baked in an oven, and those of Duhamel and Bonnet with moss,* prove the same thing.

Other natural philosophers have pursued the same inquiry: Tillet, in particular, made a number of experiments, to ascertain whether water and air were the only substances necessary for the growth of plants. He filled several pots with different earthy matters, some with old plaster, others with pure river sand, fragments of stone broken to powder, &c.; buried them partly in the ground, to retain the moisture; and sowed wheat in them. The wheat produced very fine ears; and the grains, being sown, produced other fine plants.

From the infant state of chemistry, at the time, however, none of the plants produced by means of air and water alone were analysed. This indeed has since been done; and it has been advanced, that plants growing in such a manner as to have been nourished by water alone, did not furnish as much carbon as was

* Mr. Procopius Densidoff of Moscow, sows seeds in moss, where they germinate, and then plants them in pots. In this way he loses very few seeds of those that grow with most difficulty. *Note of Prof. Willmett.*

contained in the seeds from which they sprung; while those in mould were much more vigorous, in consequence of the carbon with which it furnished their roots. But these experiments were on too small a scale to furnish satisfactory results; and I have therefore attempted to investigate the subject anew, in order to ascertain, how far this opinion is well founded.

As a preliminary step, I conceived it necessary to analyse vegetable mould in a state of perfect decomposition. For this purpose I selected perfectly pure, black, pulverulent mould, from among the hollow roots of a very old tree. Distilled water, in which it was boiled, remained colourless after filtration, and on being evaporated left no sign of any soluble matter.

A hundred grammes [$3\frac{1}{2}$ oz.] were reduced by dessication to 20, which shows it to be extremely retentive of water.

These 20 gr. distilled at a red heat, gave out 4 of water, that powerfully reddened infusion of litmus; and contained empyreumatic acetous acid, partly saturated with ammonia; 2 of an acrid oil, that congealed on cooling, and was of a dark brown colour; 89 cubic inches of oily hydrogen gas, burning with a blue flame; and 34 cubic inches of carbonic acid absorbed by lime.

The coally residuum weighed 8·5 grammes, which were reduced by incineration to 2·4 gr. of light yellow ashes.

Boiling distilled water digested on these ashes acquired no peculiar taste, did not turn syrup of violets green, and was barely rendered turbid by the addition of a few drops of oxalic acid, which seemed to indicate, that a few particles of lime had been set free by the calcination. The nitrates of barytes and of silver produced no change in it. On farther analysis these ashes afforded 1·3 of a gr. of silex, ·2 of oxyde of iron containing a little oxyde of manganese, ·25 of phosphate of lime, ·2 of lime, and some traces of magnesia.

I boiled 6 gr. [92 grains] of the same mould for an hour, in a strong solution of caustic potash, when it became glutinous, and swelled up. I then diluted it with water filtered, and obtained a very deep brown liquor. This mixed with the lixiviating waters gave on the addition of an acid a precipitate, that weighed 1 gr. when dried. It was of a very black colour, and in little shining scales. Scarcely any vapour arose from it when thrown on burning coals, and I consider it as charcoal well saturated with hydrogen Art may imitate this substance, by effecting by fire what nature does by time. If we deprive a vegetable substance

of almost all its oxygen, and a small quantity of its hydrogen, by exposing it to a certain temperature, the result will be a hydroguretted charcoal, partly soluble in potash, as I have found by experience.

That part of the mould, which had resisted the action of potash, weighed when dried 5 gr. It had no longer the physical characters of mould; was in pieces that were tolerably hard and brittle; and had a striking resemblance to pitcoal, which led me to produce it in larger quantity. In this way it had still such a resemblance to coal, that I could compare it to nothing else.

From this examination of mould it appears, that it cannot supply plants with any soluble matter for their nutrition, since boiling water has no action on it. It would be superfluous to say, that seeds sowed in it vegetated with extraordinary vigour; but I must not omit to mention the presence of a large quantity of potash in the plants, though I could not detect any in the mould in which they grew, by the most strict researches.

These observations appear to corroborate the opinion of Tillet and Parmentier, who consider manure as useful only by retaining moisture, and keeping strong soils open for some time, so as to allow the roots of plants to penetrate them. But if water and air be the only sources of the food of plants, any insoluble matter, sufficient in quantity, and duly watered, must be adequate to the purpose of their growth. This I endeavoured to ascertain by experiments.

Exp. I. In a box filled with pure litharge I sowed 400 seeds of white mustard, weighing 2·2 gr. These I watered frequently and carefully with distilled water. The box was placed in a good aspect, and a glass was hung over it to keep out the dust. The plants throve very well, and produced perfect pods. I collected all the seminal leaves as well as the rest that dropped off; and when the vegetation was at its height, pulled up the plants. Having well washed the roots, to remove any portions of oxyde of lead, and wiped them dry, the whole weighed 264 gr. After they were dried, the weight was 34·2 gr.

These yielded 12 gr. of coal, which by incineration were reduced to 4·2 gr. of ashes. These lost by lixiviation 2·2 gr.; of which ·59 gr. were sulphate of potash, ·69 gr. potash. The insoluble residuum afforded ·4 gr. of silex; ·45 gr. of oxyde of iron, alumine, and phosphate of lime, the proportions of which were

not determined; ·57 gr. of oxyde of iron; and a very small portion of magnesia.

Exp. II. In a very large, deep, and perforated bowl of stone ware, filled with well washed flowers of sulphur, 250 seeds of white mustard were sown. The whole was covered with a large bell glass, allowing free access to the air and light. The plants grew vigorously, being frequently watered with distilled water; as sulphur, having little affinity with water, parts with it very easily, and dries on the surface. They produced flowers in tolerable abundance, and the seeds produced plants in common ground. The weight of the fresh plants, with the fallen leaves, was 108 gr.; and when dried 18·6 gr. Their coal weighed 7·8 gr. and left 1·55 gr. of whitish ashes, which afforded by lixiviation ·6 gr. of carbonate and sulphate of potash. The insoluble part was similar to that of the former.

Exp. III. A hundred seeds of white mustard were sown in twenty pounds of very small unglazed shot, on the 9th of July. On the 28th of August they began to flower, and afforded small pods. All these plants were slender, and had but few and small leaves. When fresh they weighed 10 gr. and after being dried 2.3 gr. they yielded very little coal, but more than the weight of the seed. The weight of the shot appeared to oppose too great an obstacle to the young roots, as most of them spread over the surface, without being able to penetrate it. The little affinity of the lead for water was another reason of the feeble growth of the plants; and hence I have found, that plants thrive less in metallic powders, than in their oxyds.

Exp. IV. On a flat stone pavement a bed was formed, about a yard high, of fine sand, taken immediately from the bed of the river, and well washed. In this were sown seeds of the common radish (*raphanus sativus*) which were frequently watered with perfectly pure rain water, and the plants grew with as much vigour as they would have done in any ground. The greater part of the radishes were brought to table, and were of a very delicate flavour, without any of the disagreeable earthy taste they have sometimes. Some of them were left to seed; and most of these grew to the height of 2 feet or 2½. It was observed, that those at the top of the heap were much larger and stronger than those near the bottom.*

* A skilful gardener informs me, that asparagus too will succeed very well in pure river sand. Potatoes also grow well in sand, and are said to be better tasted.

Sixty-three of these plants when dried weighed 372 gr. Incinerated they left 54.2 gr. of gray ashes. These afforded by lixiviation 18.6 of very fine potash. From this I am inclined to think, that the radish might be cultivated with advantage on wet sandy places by the sea shore, for the purpose of fabricating potash.* These 18.6 gr. being farther analysed, were found to contain 6·7 of pure potash; 7·35 of sulphate of potash; a small quantity of phosphate of lime; and the rest was carbonic acid.

The residuum left after lixiviating the ashes appeared to contain sulphur, as on pouring nitric acid over it sulphuretted hydrogen was given out; but I could not find any phosphoric acid in it. I did not examine it for the earths, as these might have been said to have been taken up from the sand.

* It appears, that potash abounds in all the plants of the class tetradynamia, and the ashes of some of the species were long in use for making soap and glass, before the introduction of soda as an article of trade. According to Bomare, the bunias cakile, sea rocket, was much employed for these purposes.

I must here add an observation, which appears to me pretty general, and which I made in examining the acrid and bitter properties of plants. One or other of these principles I have almost always found in conjunction with a large quantity of potash, which was frequently saturated with nitric acid. Thus among the cruciferous plants, which are all more or less acrid, the sisymbrium nasturtium, common water-cress, afforded me a great deal of alkaline matter after incineration; and when fresh I found in it nitrate of potash. I have observed the nitre melt on incinerating cabbages and turnips; and Mr. Delaville found this salt in large quantity in the sap of these plants. Mr. Bouillon-Lagrange found a large quantity of potash in the ashes of the erigeron canadense, Canada fleabane, which is acrid. The ashes of tobacco, the acrimony of which is well known, yield 40 per cent. of potash. Among the bitter plants I have examined, I found nitrate of potash in the fumitory, 100 parts of the ashes of which contain more than 36 soluble in water, according to Wiegleb and Rukert. The common centaury, marsh and Siberian trefoil, and different species of the genus centaurea, which are very bitter, afford ashes in which potash abounds. Whether in these plants it be saturated with nitric acid I have not ascertained. I must observe, however, that I have found no nitric acid in wormwood, 100 parts of the ashes of which afford nearly 75 of saline matter, according to Wiegleb. This large quantity of alkali has appeared to me to be partly saturated with a peculiar matter, which is deposited by a decoction of the fresh plant, and may be precipitated abundantly by nitrate of lead. This matter dissolves very well in alkalies neutralizing part of their properties: it is the same that Mr. Vauquelin has found in some species of cinchona. Does it exist in all bitter plants? and is it this which in cinchona and worm-wood cures intermittent and low fevers?

Having thus examined these plants, I thought it might not be amiss to compare their produce with that of some others, which had grown in common garden mould. Of these dried 372 gr. afforded but 34 of ashes, which it is true were very saline, and yielded 16 gr. of saline matter, consisting of carbonate and sulphate of potash. In the incineration of these plants too I observed a very copious production of ammonia, on pouring a little water on their ashes while still hot.

But whence come these earths, alkalies, acids, metals, sulphur, phosphorus, found in plants, that have had no aliment but pure water? Can vitality, in conjunction with light and heat, determine certain quantities of oxygen and hydrogen to form by peculiar condensations those substances which have been considered as simple? this might put us on examining in a new point of view all those substances, that chemistry has not yet been able to decompose, and thus perhaps the conjectures, that have been advanced by some, may be verified.

We may even extend these remarks to animalization, supported by the well known experiment of Rondeletius, who kept a fish in pure water, till it grew too large for the vessel containing it, and by other similar experiments on different animals. It would even seem, that food acts on the stomach in a great measure as mould does on the roots of plants, merely retaining water in such a state of division, as to fit it for absorption and assimilation.

From what has been said it appears, that foreign matters dissolved in water only check the progress of vegetation; but that the vital powers can sometimes surmount these obstacles, appropriating only the pure water, that held these matters in solution.

If experiments founded on long practice were still necessary to prove, that the soil is so much the more proper for vegetation in proportion as it is deprived of soluble foreign matter, I would mention the practice of paring and burning wastes, used chiefly in England. Lands thus treated remain in heart a long time; the parts where the heaps of surface mould were burned are most fertile; and manure even appears to be injurious, by causing the wheat to run chiefly to straw, with thin ears, and those of bad quality.

This extraordinary effect of torrefaction on the soil appears to me attributable to the combustion of those excrementitious matters, which are ejected by the roots of plants. When the soil is

impregnated with these matters, which are eminently injurious to vegetation, the perfect developement of plants is prevented. This excretion from the roots is evident from the surrounding earth, which becomes unctuous, and sometimes of a darker colour. In several of the euphorbiums and cicoraceous plants it is very perceptible, and milky. It may be observed too, that roots, when they multiply under water, become covered with a glairy matter, which deserves to be examined; and which no doubt the earth would have absorbed, had the roots remained buried in it. It is to these excretions from the roots perhaps we must frequently ascribe that kind of antipathy between certain plants, which are never found together. Thus the thistle is injurious to oats, euphorbium and scabious to flax, elecampane to carrots, fleabane and darnel to wheat, &c.

It would certainly be wrong, to ascribe the fertility of land pared and burned to the charcoal produced in this operation; for Mr. Chaptal has shown, that dry charcoal, alone or mixed with earths of little solubility, does not penetrate into the vessels of vegetables.

To add to the proofs, that vegetables have no need of drawing carbon from the earth, I might mention high trees, loaded with fruit, that grow and thrive on rocks or old walls, totally destitute of vegetable mould; and those vast forests, the soil of which is pure sand extending far beyond the roots.

I have now to examine the opinion, that vegetables absorb their carbon from the small quantity of carbonic acid contained in the atmosphere. Sennebier first announced this decomposition; and T. Saussure afterward endeavoured to prove, that this very small quantity would be sufficient for all the vegetables that exist. But though this philosopher was persuaded of the utility of carbonic acid in vegetation, he satisfied himself, that plants could grow in an atmosphere freed from it; and he ascribed this growth to the carbonic acid produced by the plants themselves, which they decomposed after having formed it.* To prove this he exposed to the sun closed receivers, in which plants were growing, and suspended quicklime to the upper part of them. The plants soon grew yellow, and at the expiration of five days

* It is obvious, that the carbonic acid formed by the plants could not furnish them with more of its base than it had previously taken from them. *Tr.*

gave no signs of vegetation; whence he inferred, that the absorption of carbonic acid by the lime was the cause of their death, and that the elaboration of this acid was necessary to vegetation in the sun. But I cannot be of his opinion. I have examined the experiment carefully, and satisfied myself, that the death of the plants was not owing to the privation of carbonic acid alone, but to the lime itself in vapour.

The following experiments convinced me of the volatility of lime.

1. Paper tinged by repeated immersion in infusion of litmus, then reddened, and afterward washed in water to remove its excess of acid, was suspended in a stopped phial, into which I had put with great caution some lime, that was slaked, and suitably moistened with water. It was not long before the red colour of the paper was changed to blue. This effect was not unknown to Fourcroy.

2. Into a retort I put with all possible precaution a certain quantity of lime and water, and by distillation I obtained a liquor impregnated with an intolerable smell of lime. This liquor left a disagreeable impression on the palate, and had manifestly alkaline properties.

Alcohol by its volatility carries up in vapour a much larger quantity of lime, as appears from an experiment of Proust. In order to obtain spirit free from acetic acid, he distilled 25lbs. of red wine with a handful of quicklime. The product was so much impregnated with the taste and smell of the lime, that he was surprised. When redistilled it had the same taste, precipitated metallic solutions and oxalic acid, and restored the blue of litmus.

Lime is not the only fixed alkali, that shows a disposition to rise at a pretty low temperature.

A solution of potash, subjected to distillation, afforded me a water with a strong lixivial smell. This water redistilled retained the same smell, and gave with nitrate of lead a white flocculent precipitate, which was completely soluble in distilled vinegar.

But there are other substances besides alkalies, the volatility of which is so little apparent in the temperature of the atmosphere, that it is discoverable only from its effects on organized beings.

Some Dutch chemists set plants in water, by the side of which they placed a small bottle of mercury, and covered the whole with a jar standing in water. On the third day the plants were co-

vered with black spots, and on the fourth, the fifth, or at latest the sixth, they were entirely black. The effects were the same when the jar rested on pieces of cork on a table. Other plants lived a long time under similar circumstances except the presence of mercury.

Sennebier and Hubert too have shown, that the vapour of sulphuric ether prevents germination from taking place, without altering the quantity of the air. Camphor, oil of turpentine, assafetida, vinegar, ammonia, bodies in a state of putrefaction, &c., have the same effect. Hence we may infer, that all those matters, which are injurious to animals, sensibly affect vegetables likewise.

We cannot therefore lay much stress on Saussure's experiments to show the utility of carbonic acid in vegetation, particularly when we recollect an experiment of Priestley's, which proved that an atmosphere with an eighth part of carbonic acid was sufficient to kill two plants of mint, though this small quantity of acid was in contact with a large surface of water.

Having found by experiment, that seeds germinate very well in oxydes of lead, which are known to be greedy of carbonic acid, I conceived, that these might contribute to elucidate the question respecting the utility of carbonic acid in vegetation. In consequence I moistened with distilled water some recently prepared oxyde of lead in the first stage of oxydation. This mixture I introduced speedily into a flint glass bottle : and though the disagreeable and as it were alkaline smell that arose from it, led me to doubt the success of my experiment, I sowed some mustard seed in this oxyde, and corked the bottle tight. As I foresaw, no germination took place : but what I was far from expecting, and to my great surprise, part of the oxyde of lead in the water was reduced by the seeds, each of which was enveloped by a shining coat of metallic lead. This appeared to me to be very probably owing to a production of water by the union of the oxygen of the oxyde with the large quantity of hydrogen, that is condensed in this oily seed, which after the reduction was more or less carbonized.

If the oxyd of lead be left exposed to the air for some time after it is made, and then put into a bottle with water and seeds, no reduction of the metal will be effected, but germination will take place.

(To be Continued)

SUGAR FROM STARCH.

The interesting experiments of M. Kirchoff, of St. Petersburgh, proving that starch may be converted into sugar by the action of diluted sulphuric acid, have been eagerly repeated by the most distinguished chemical philosophers in Europe. This singular conversion is produced by boiling 100 parts of starch with 400 of water, and from two to eight parts of strong sulphuric acid, in an unglazed earthen vessel, for a period of from 24 to 36 hours, constantly stirring the mixture during the first hour, (after which it becomes more fluid) and carefully maintaining the original quantity of water by adding more as it is wasted. Upon growing cold the mixture must be neutralized with chalk, and clarified by charcoal; filtrated through flannel, and evaporated to the consistence of oil. It must then be again cooled, in order to remove its sulphate of lime, and the clear liquor, if further gently evaporated, will yield about 100 parts of gummy syrup of the specific gravity of 1,295, easily susceptible of vinous fermentation, and when separated from the gum, which in general forms no less than a fifth part of it, capable of being crystallized, and applied to all the common purposes of native sugar. With the rationale of this very important transmutation we are not yet acquainted. It is plain, however, that the acid still exists undecomposed, and there is reason to believe that the quantity of water is increased. The probability therefore is, that the agency of the acid is exerted in abstracting from the starch a part of its hydrogen and oxygen, in the proportions requisite to form the excess of water, and in thus enabling its remaining principles to be in such a way arranged as to induce the extraordinary change effected.

COOKERY.

TO THE EDITOR OF THE EMPORIUM.

My good Friend,

YOU are about publishing a periodical work, which to please the class of readers likely to purchase it, must be, in great part, not so much an instructive, as entertaining compilation. It must be light, superficial, miscellaneous, desultory, full of well executed

plates, well printed, and so forth. Now if I know you well, (and I think I do) you will stuff it full of matter of fact; condensed, and screwed, and pressed, and packed into as small a compass as possible; containing as much solid meat for the mind as a hard stuffed Bologna sausage for the body; and almost as indigestible to the generality of readers. You will be apt to forget the wholesome advice of Horace, *omne tulit punctum, qui miscuit utile dulci.* You will make the useful useless, by neglecting the agreeable. You are anxious to instruct your readers; if you succeed you will do well: try to amuse them; if you succeed you will do better. Remember, when we leave school, we seldom allow any thing but the bottle, to *pang us fu' o' knowledge.*

I have thought of this: and as you well know that I most sincerely wish success to you and to your undertaking, I will, with your permission, tax my brains once every now and then, to give you aid in *my* way.

You have somewhere extolled the great importance of the ART OF COOKERY, which I regard as the first in importance among our *domestic manufactures:* and I therefore presume, that you will not object to a little theoretical, and a little practical knowledge being occasionally offered to the palates of your readers, on a subject that I am strongly inclined to think, both they and you hold in higher estimation than either of you choose to confess.

If you allow me a few pages of your Emporium for this purpose, I shall follow the advice I have given to you, and serve up my courses in a very desultory way; sometimes learnedly dissertin on the history of this manufacture, sometimes treating it philosophically and chemically, sometimes popularly, and sometimes with practical recipes for the poor as well as the rich; for the art of cookery

Æquè pauperibus prodest locupletibus æquè

and presides as scientifically over the processes of the benevolent soup shops of England, as over the matelots of Paris, or the calipash and calipee of the West Indies.

Nor is the next line of the poet less true

Æquè neglectum pueris senibusque nocebit.

that is, a bad cook is the worst of plagues both to old and young.

But Cookery as you well know, is not only a chemical manufacture in every part of it, but I shall take occasion hereafter to show, that much statistical knowledge, and many abstruse questions in

political economy, and even in tactics, are connected with and dependent upon the science of cookery; so that I shall gratify you greatly some time or other, by the depth of my researches on this subject; and you will not have to tax me with converting your Emporium into an *Almanac des Gourmands*. I would not say it for the world unless to yourself, but I greatly fear, my good friend, you will not make the Emporium either so pleasant or so popular, as that very lively publication. Some of your grave sober people may be shocked at such an attempt, and think it beneath the dignity of a serious work to entertain such disquisitions; but that man has lived to little purpose in the world, who does not know, that, for the most part, the high road to the heart is through the stomach. Look at the practice of the old country—Where is the business of the nation transacted? In the house of Lords, or of Commons? No: but at Cabinet-dinners. Can any patriotic measure be adopted that is not ushered in by a public entertainment? Does not the tide of public virtue flow strong in proportion to the oceans of port the company pour down? And with us, how quickly do we swallow the *sober* 16th bumper to the American fair, that we may shine out in patriotic volunteers? Look at all your charitable corporations—do the governors and directors of your hospitals and infirmaries in and about London, ever attempt a public subscription but at a dinner-meeting of the subscribers and their friends? It is true, the dinner is usually ushered in with a charity sermon by some dignified church-man, and voluntary with a presto movement, by some noted organist, but the contemplation of what is to come, the picture of the table in the mind's eye for an hour before hand, is an excellent stimulus, not only to the appetite for food, but the disposition for charity: nor does the reverend Dignitary ever refuse to grace the good things provided on such a laudable occasion. And this is right.

For my own part, I profess myself in direct opposition to all the principles and practices of anchorites and ascetics. I hold, that all wilful contempt and neglect of the bounties of nature—all obstinate refusal of gratifications that can be safely, conveniently, and innocently enjoyed, has in it something approaching to a sin of omission: it is a proud rejection of the means of happiness offered to us by the Creator of the universe; especially as the chearful use without abuse, even of convivial pleasure, has been repeatedly sanctioned by authority, which it suffices barely to hint at with becoming reverence.

When I hear a man say, "I never care what I eat or drink," I set down the remark, either as proof of affectation not founded in truth—or of sordid and miserly attention to worldly gain, that improperly absorbs all the thoughts—or of gross ignorance and incivilization. Why has the benevolence which framed our system, set before us, choice without end, but for the purpose of enabling us to choose? and the power of encreasing the zest of every pleasure, but that we may exercise it? Such a man may be a fit companion for the St. Simeons and St. Anthony's of former times, for a Hottentot or a new Zealander, a miser or a misanthrope of modern days, but he is not exactly fitted for good society in any sense of the word. I know of *no use whatever* attendant upon civilization, but the means it affords, and the skill it confers, of multiplying all our enjoyments, and indefinitely encreasing their powers of exciting pleasurable sensations. In my humble opinion, all happiness depends upon our wants and desires; the more numerous are these sources of gratification when they can be gratified, the happier the being. A stone has no wants and therefore no pleasures; a brute has few, a man in a state of nature more, but the wants of civilized, cultivated man, are innumerable. They are permitted to arise for the very purpose of promoting our happiness; they are the rewards of social improvement; and the human creature who neglects any pleasure within his reach, which he can *innocently* and *prudently* partake of, or sullenly refuse to cherish every want that his situation in life permits him *innocently* and *prudently* to gratify, is in my mind worse than unwise.

With respect to cookery in particular, I should be glad to know, whether that science whose aid we require twice or thrice in every day of our lives,—that science which teaches us to give sapidity to insipid substances—to heighten the flavour and encrease the nutritious power of food—to prevent the innumerable evils of indigestion arising from ill prepared nutriment—that science, which promotes the savings and encreases the enjoyments of the poor—which contributes to comfort, by inculcating cleanliness and economy—which banishes waste and therefore want—which gives habitual feelings of cheerfulness and good humor, by making every social repast equally wholesome and pleasant—and diffuses the light of practical philosophy among the lowest classes of society—I should be glad to know, I say, why such a science, is not as well worth pursuing, and as important to the world, as one that teaches us to give a brighter tint to a ribband, a clearer hue to the varnish of a tea-board, or a higher polish to a pair of scissars.

I am not concerned about the gloomy theories of Malthus, who has contrived to spread out through the heavy pages of a bulky quarto, but one, single, long-told, well-known truth, that "population is regulated by the means of subsistence, and that excess is usually counteracted by vice, war, pestilence or famine." I acknowledge that population depends upon subsistence, and therefore I assert, that next to agriculture which provides the raw material of food, Cookery among the arts, ranks highest in importance. For it teaches us so to manufacture the raw material, as to make it more economical, more grateful, more nutritious, and more digestible. I hope hereafter to explain the reason, why it is, that where Frenchman would live luxuriously, an Englishman or an American would starve. Swift said, that the man who should make two blades of grass grow, where one grew before, would rank among the greatest benefactors of mankind: nor is he less so, who can make that quantity of food nourish two people, that was heretofore consumed by one.

Neither do I believe in the old adage, *plus occidit gula quam gladius;* the appetite kills more than the sword: and if it were true, I would certainly rather die of turtle soup, than a *Coup de Sabre*, if it were left to me to determine the mode of exit. For my own part, I scruple not to acknowledge the wisdom of the poet's advice;–

> Let sages pretend to despise
> The joys they want senses to taste;
> But let us, seize old time as he flies,
> And the blessings of life while they last.

To all this I would add no restraint but the two maxims which regulate my theory: *use without abusing: cherish no want, that prudence forbids you to gratify.*

But that I may begin in regular order, I must follow the example of other scientific men; and as you chemists explain to your students in the outset of your lectures, the terms of art you propose to employ, such as solution, saturation, precipitation, distillation, sublimation, volatilization, condensation, effervescence, efflorescence, oxygen, hydrogen, &c. &c. I must explain the terms of art in my science also. Chemists, like the Romans of old, draw upon the Greek Language: every word, is legitimate *si graæco fonte cadat:* the French, is *our* Greek Language; and their writers our classics on the subjects in question. I am not a thorough Frenchman, but we may be allowed to acquire knowledge wherever we can get at it; *fas est et ab hoste doceri.* You must for-

give these scraps of Latin: "Tis my vocation Hal," as Falstaff observed; Cooks, you know, are professionally addicted, to *interlarding*.

I begin then, with an explanation of technical terms. And I must observe, that much as the knowledge of women is undervalued, I do not believe that one half of the chemists in Europe, either pay so much attention to the theory of their science, or superintend so many, and such a variety of important and complicated experiments, as we require in general from well educated women. They are expected as a common accomplishment, to direct with elegance and economy the appointment of the table; and to do the honours of the entertainment, not only with easy dignity, but in so doing, to recommend with science and with skill, the various dishes that may tempt the indulgence of appetite, and promote the pleasures of the repast.

I give the following table of explanations, because those great men, the lexicographers, the compilers of Encyclopædias, and circles of sciences, think themselves above the contemptible science of Cookery, and give us neither knowledge of the art, or explanation of the terms. Although these wiseacres of literature, were in my time, by no means averse to Mr. Dilly's dinners.

But the really great men and wise men of the world, have been, not gluttons and gormandizers, like Apicius or Heliogabalus, but Epicures; whose pleasures were enjoyed when they had leisure for pleasure, with discrimination, elegance and taste. Indeed, what is taste, in its original signification, but the science of eating? so of cheerfulness, what is it but the habitual good humour of a man accustomed to indulge in good cheer—cheer-full?

Alcibiades and Pericles were Epicures: so was Lucullus: so was Julius Cæsar: so was Augustus: and Mecenas. So was old Fritz of Prussia: and so is Buonaparte; who has directed his chief pharmacist Mr. Cadet to institute and publish a series of experiments on the best mode of making Coffee, and who has sanctioned the receipts of M. Appert, on the art of preserving viands by exposing them to heat in close vessels.

No man who has seen the busy, good humoured complacency with which Mr. Fox used to tuck his napkin into the second button hole of his waistcoat on sitting down to table——or who has cast his eye on Mr. Pitt's plate and Mr. Pitt's bottle at Grocer's hall ——or who has perused the facetious sarcasms of brother Peter on Mr. Percival's soup and claret——can pretend that the dull compilers of Dictionaries and Encyclopædias, have a right to turn

up their noses at the description of a good dish or a good dinner. That right courteous and accomplished Knight, Sir Kenelm Digby, seems to have furnished from his own collection, most of the receipts, that Howard his cook afterward published: one of the best books of cookery extant, we owe to Sir John Hill; and your colossus of literature Dr. Johnson, was notoriously enchanted with the charms of a well appointed table.

Supported by the practice and opinions of so many warriors and sages, have I not a right to say that the subject is not beneath the dignity even of your Emporium? and that your Honour may now and then without derogation from the dignity of a professor's chair, accept of my mite thrown into your treasury of knowledge?

Enough of apology; and now to business. The following vocabulary will enable your readers to understand in some degree, the technical phrases of the French kitchen, not easily attained elsewhere. The French cookery certainly unites the following qualities: 1st It possesses more artificial flavour: 2ly It dissipates less, the natural flavour of meat: 3ly It does not waste the meat itself: 4ly It renders food more digestible and nutritious: 5ly It combines a more wholesome and judicious mixture of animal and vegetable food: 6ly It economises fuel: and 7ly It is not so laborious, or so hurtful to the eye sight, as the English or American practice. All these points, I will some time or other, endeavour to illustrate.

Terms used in French and English Cookery.

A

Aspic: any sharp fragrant sauce.

Aloyau: sirloin of beef.

Ail-poireau: Spanish garlic. Allio-prasum scorodoprasum, Rocambole.

Ail: common garlic; allium sativum. Gousse d'ail, clove of garlic.

Andouilles: chitterlings.

B

Bouillie: beef long, and slowly, stewed till quite tender.

Bouillon: broth.

Baignets: Fritters.

Ballon: round like a ball.

Barder: to cover fowl or veal with thin slices of bacon.

Bagatelles: thin slices of seasoned meat rolled up like a sausage, tied and stewed.

Becasines: snipes.

Bechamel: white cullis, white sauce or gravy.

Blanquet: a hash-fricassèe of white meat.

Blanch: to whiten, for which purpose, to scald (as almonds): to soak in water (as fresh meat), &c.

Blanc-mangè: Blamange: white food: usually milk thickened with isinglass, sweetened, spiced, flavoured, and sometimes coloured, as Jaune mangè.

Brill: a kind of turbot.

Braze: } to stew gently over a charcoal fire.
A la braise: }

Breche: the spit.

Bresolles: collops.

C

Catch, catching: to adhere to the bottom of a pan.

Calves-cauldron: calves tripe or chitterlings.

Caramel: glazing.

Cardoons: a kind of artichoke.

Canelon: gun-shaped: sausage-shaped.

Canè de veau: neck of veal.

Crepinette de Gordeveau: veal fried with forcemeat.

Cuisseau næud: knuckle of veal.

Chibbol: small onions.

Champignons: small mushrooms.

Consommè: strong, clear, jelly-broth.

Court bouillon: stewed with wine and sweet herbs.

Cullis: Coulis: an extract of meat, flavoured, seasoned, and strained; to be kept in reserve, to give strength and flavour to other dishes of the same kind of meat.

Consommè: a strong, clear, jelly broth.

Court bouillon; stewed with wine and sweet herbs.

Cervellas: sausages.

Collotte: a rump of beef.

Compote: any thing stewed, with turnips, carrots, and small mushrooms.

Chowder: a New England dish, consisting of fish cut in pieces, seasoned, and stewed with alternate layers of sea-biscuit and fried bacon; in a covered pot with parsley, and onions.

Culotte: a saddle, as of venison or mutton: the rump.

Coul or caul: the fat membrane, that covers the outside of the intestines.

Corkants; ornamental paste.

Cotelettes: cutlets; properly, the small ribs.

Confitures: preserves; sweet meats.

D

Daub or dobe: meat larded with lardons, or thin slips of gammon or bacon.

Darde: a large slice of fish cut lengthways.

E

Entrèe: a course of dishes, with Sauces, Patisserie and Laitage;

Entremets: small plates of sallad, omelets, &c. placed between the main dishes. It was anciently used for the amusements that intervened between the courses at a grand entertainment.

Eschalots: shalots.

Estragon: Terragon, for salads and vinegar; the vinegar de Maille, is an infusion of terragon and shalots. Terragon, is the Artimisia dracunculus.

Etuvèe, a l'etuvèe: stewed on a stove.

F

Four: a la four; baked.

Fricandeau: meat larded, brazed, and then glazed with a gravy caramel.

Fricassèe: stewed and thickened with a liaison, (which see.)

Filets: long slices, usually from the neck.

Flee: Hog's seam.

Farcie: forced meat.

Friture: the sauce in which any thing is fried.

Fritters: small pancakes: usually fruit, thinly sliced, dipped in batter, and fried.

Frites: fried.

Fumet: high flavoured game.

Frais: fresh.

Fraise de veau: Calve's caldron.

G

Grits: groats: shelled oats, or wheat, used in the north of England and in Scotland with meat.

Gras: fat meat.

Gratin: the concentrated brown gravy, or juice that adheres to the bottom of the pan.

Grenadins: small fricandeaus.

Girkins: small cucumbers for pickling.

Grillè: broiled.

Gigot: a leg.

Gateau: a meat cake.

H

Hors d'ouvres: small savoury dishes; Relishes, as anchoves, Sausages, Oysters, &c.

Harricot: meat half fried, and then stewed with herbs and roots. Kidney beans.

Haslets: liver, &c. of Hogs.

Hatereau: a haslet.

Haggis: a sheep's paunch stuffed with fowl, forcemeat, groats, onions, herbs, &c. much used in Scotland.

I

Jus. Gravy.

L

Laitage: dishes of which milk is the basis.

Liaison: any intermedium to make two substances mix, that would not mix otherwise, as an egg to oil and vinegar. Any thing used to thicken gravy, and make the gravy and the fat unite in an uniform mixture, as the yolk of eggs. The Liaison must never be put in the fluids while boiling.

Lazagne: an Italian paste.

Lard: Bacon proper for larding. Hog's fat clarified: often used in cookery instead of butter.

Lardoons: Lardons. Bacon cut in thin slices and inserted in the flesh of meat that requires juice or flavour. Long, small strips of fat bacon inserted in meat by means of a needle, called a larding needle.

Lentils: such vegetables as are contained in shells and husks, as pease, beans, &c. A small pulse, of a lenticular, or double convex shape.

Leveret: a young hare. In the northern parts of New York and Pennsylvania, they are some times found in the winter, white.

M

Macaroni: a sweet, very thin, tubular biscuit.

Matelot: a hotch pot, a sailor's dish: a very favourite French dish, made of carp and eels, cut in thick pieces, washed, seasoned with pepper, salt, and spice (either with or without sweet bread, oysters, or lobsters) and stewed with strong gravy, claret or red port, with trufles, morells, small onions and champignons, or button mushrooms.

Marinade: to soak in a pickle previous to dressing.

Marmalade: Jelly of the pulp of fruit.

Meagre: Soup Meagre: without flesh meat.

Mignionette cloth: a small bag.

Morelles: see Trufles.

N

Nosegay: a small bundle or faggot of sweet herbs; such as parsley, celery, chervil, thyme, marjoram, savory, rosemar, tarragon, Cay-leaf, &c. tied up with thread.

O

Omelettes: Pancakes of Eggs beat up, either alone, or with gammon shred fine, grated cheese, &c.

P

Plateau: the silver tray, or mirror that supports the ornaments and flowers in the middle of the table.

Pate: Pates. Paste. Patties.

Patisserie: Patties; Pastry.

Poupeton: a meat pudding.

Poivrade: a peppery sharp sauce.

Papillotes. broiled in paper.

Paupiettes: olives of meat.

Potage: soup.

Purèe: a strained soup; pease soup made with English or Albany pease well boiled in meat soup, and strained through a sieve, served with dried mint on the top. The pole-bean of this country answers tolerably well; but nothing is so good for the purpose as the English split pea.

Q

Quenelles: force-meat balls.

R

Restaurateur: the keeper of an eating house: one who professes to compose nourishing and restorative dishes.

Restaurant: a strong broth or cullis, made of meat, fowl, and game.

Ragout: any dish stewed with herbs and onions, high seasoned.

Reveil: to quicken the palate.

Rocambole: Spanish garlic, not quite so strong as the common garlic, but stronger than shallot.

Rissolles: }
Rissollettes: } Browning. Any thing fried brown, as Collops, or force-meat.

Remoulade: mustard sauce, with horse radish and shalots.

Ravigotte: a piquant, relishing sauce.

Ramequins: cheese cakes.

Roumestèe: Jelly broth of fragments.

Rouelle: a small filet.

Rognon: kidney.

Rots: Roties: roast meat, fowl or game.

S

Stock : strong broth ; coulis or cullis.

Semouille : an Italian paste.

Simmer : a heat much short of boiling.

Salpicon : a ragout, or a farcie of liver : stuffing.

Salmix : a hash made at table of meat half drest for the purpose ; as venison, ducks, &c.

Salamelec : hotch pot.

Surprize : disguised meat ; covered with force-meat.

Saucisses : Cervelas : sausages.

T

Traiteur : one who furnishes dinners at so much per head.

Tourte : a pie or tart ; often of meat, fowl, or fish.

Tartlets : paste baked with preserves put on it.

Timbale : a mould.

Trufles : Morelles : Morilles : the trufle is the subterraneous Lycoperdon, about the size of a potatoe, found 3 or 4 inches under ground in clusters, and weighing from 2 to 4 ounces. It is used to give richness and flavour to sauces like the champignon or mushroom.

Morelles. Morills, are the agaric of decayed wood, having a thick fleshy curled cap, pierced with holes. They are used for the same purpose as mushrooms, and trufles ; and all of them, whether fresh or dried, or in powder, are excellent additions giving fullness and sapidity to sauce.*

V

Volailles : an entrè or course of wild or tame fowl.

* In this our soi-disant civilized Country, where the proper use of baths hot and cold is almost unkown—where we have neither hot walls, espaliers, or hot houses—where grapes which might and ought to be as plenty as currants, are scarce and dear—where apricots and nectarines, the finest of European fruits are hardly eatable—where the pine apples imported, instead of being grown here, are the refuse of the West India fields—where a good orange is *never* seen—where artichokes, and even cauliflowers and brocoli, are actually curiosities—where steam is unknown either as a medicinal bath, or to warm dwellings, to cook vituals, or to force hot house plants ; and is but just known as a power to move machinery—where in our cities in summer, we are content to be stewed in brick ovens with the roofs off, called streets ; and in our houses in winter, to expose our faces to be broiled, and our backs to be frozen—in this country, I say, we have no cultivated mushrooms, we have no trufles, we have no morells : even ketchup and anchovy liquor are almost unknown, and for soy, you may enquire in vain.

"Why then if you can't do without them, and dine upon on a plain dish, "you ought to starve."—

TO THE EDITOR.

Sir—A publication of the following curious calculations on weights and measures, &c. will probably gratify your scientific readers, and diffuse useful information to your subscribers in general.

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WEIGHTS AND MEASURES, &c.

From a course of lectures on Natural Philosophy and the Mechanical Arts, by Thomas Young, M. D. 2 *vols. 4to.—London. Price J5 5s.—Johnston*, 1807.

The English yard is said to have been taken from the arm of king Henry I. in 1101.

Graham found the length of the pendulum vibrating seconds accurately, equal to 39-13 inches. *Desaguliers.*

Bird's parliamentary standard is considered as of the highest authority, it agrees sufficiently with sir George Shuckburgh's and professor Pictet's scales, made by Troughton.

The royal society's standard, by Graham, is perhaps about a thousandth part of an inch longer than Bird's; but it is not quite uniform throughout its length.—*Maskelyne Ph. Tr.*

The standard in the exchequer, is about ·0075 inch shorter than the yard of the royal society.—*Ph. Tr.* 1743.

General Roy, employed a scale of Sisson divided by Bird. He says it agrees exactly with the tower standard on the scale of the royal society.—*Ph. Tr.* 1785.

Taking Troughton's scale for the standard, sir G. Shuckburgh, finds the original tower standard 36.004; the yard E on the royal

An Esquimaux or a Laplander, with his dried fish and train oil, or a Border-Indian with his jerked venison and bear's fat, might with equal ignorance and stupidity, make a similar exclamation! I know of nothing so debasing, nothing so characteristically brutal, as the indiscriminate satisfying of mere animal appetite.

But let us consider: is there any thing which ought to be called knowledge, but what consists in the methods of alleviating pain, and producing, promoting, prolonging, and communicating grateful, pleasurable feelings? Is there any use whatever of riches, but as they contribute to the same good purpose? If this be true, then is that man a public benefactor, who in any manner improves the theory of pleasurable sensations. Who contibutes to promote cheerfulness by good cheer, and to cultivate TASTE, whether as applied in its literal, or its metaphorical meaning—whether to the pleasures of sentiment or the pleasures of sense. Adieu. *Epicuri de grege Porcus.*

society's scale by Graham, 36,0013 inches; the yard exchequer of the same scale, 35.96933; Roy's scale, 36.00036: the royal society's scale by Bird 35.99955: Bird's parliamentary standard of 1758, 36.00023.

The English standards are adjusted and employed at the temperature of 62° of Fahrenheit's thermometer; the French at the freezing point of water.

The French metre, the ten millionth part of the quadrant of the meridian, is 39,37100 English inches.—*Pictet and Journ: R. I.*

The metre has been found to contain 36.9413 French inches, or 3 feet 11.296 lines

Hence the French toise of 72 inches is equal to 76.736 English inches. One of Lalande's standards measured by D. Maskelyne, was 76.732; the other 76.736—*Ph. Tr.* 1765.

In latitude 45° a pendulum of the length of a metre would perform in a vacuum 86116 5 vibrations in a day. *Borda.* The length of the second pendulum is 993827 at Paris.—*M. inst:* 11.

Allowing the accuracy of the French measurements of the arc of the meridian, the whole circumference of the globe will be 24855,43 English miles; and its mean diameter 7911.731.—*Journ. R. In.*

A bushel of wheat, at a mean, weighs 60 pounds; of barley, 50; of oats, 38.

[It is settled law, that no sale in England is valid by any other bushel than the Winchester bushel: which by act of Ap. 1697, must be a cylinder with an even bottom 8 inches deep and 18½ diameter. This vessel will contain 2150,42 cubic inches.]

A chaldron of coals is 36 heaped bushels, weighing about 2938.

Ten yards of inch pipe contain exactly an ale-gallon, weighing 10 2-9th pounds.—*Emerson.*

The old standard wine gallon of Guildhall, contains 224 cubic inches.

By an act of queen Ann, the wine gallon is fixed at 231 cubic inches.

It is conjectured, that some centuries before the conquest, a cubic foot of water, weighing 1000 ounces, 32 cubic feet weighed 2000 pounds or a ton; that the same quantity was a ton of liquids, and a hogshead 8 cubic feet, or 13824 cubic inches, one sixty-third of which was 219,4 inches, or a gallon. A quarter of wheat was a quarter of a ton, weighing about 500 pounds and a bushel one eighth of this, equivalent to a cubic foot of water. A chaldron of coals was a ton; and weighed 2000 pounds.—*Barlow.*

At present, 12 wine gallons of distilled water weigh exactly 100 pounds avoirdupois.

A hundred English wine gallons of common air weigh a pound avoirdupois.

On the subject of labor of workmen, Dr. Young observes:

In order to compare the different estimates of the true force of moving powers, it will be convenient to take a unit, which may be considered as the mean effect of the labor of an active man, working, to the greatest possible advantage and without impediment; this will be found, upon a moderate estimation, sufficient to raise 10 pounds, 10 feet in a second for 10 hours in a day: or to raise 100 pounds, which is the weight of 12 wine gallons of water, 1 foot in a second.

For every minute that a clock varies in a day, a second pendulum must be altered 2-37 or .054 inch. A half second pendulum 1·74 or .00134.

Rain and Dew.—Dalton makes the mean for England and Wales 36 inches amounting in a year to 28. cubic miles of water, that is 7-12, and thinks that the Thames carries off 1-25 of the rain and dew that falls in England; other rivers 8 times as much, making together 13. inches and leaving 23. for evaporation.

MAGNESIAN LIMESTONE.

Some time ago the honourable *Richard Peters*, of Belmont, near Philadelphia, requested I would take the trouble of analysing some limestones for the purpose of ascertaining the quantity of magnesia they might contain. In England, the impression among scientific men, in consequence of the experiments of Mr. Tenant, in Phil. Trans. 1790, are, that limestone containing a considerable quantity of magnesia, such as the limestone of York, in Yorkshire; Bredon, in Leicestershire; Matlock, in Derbyshire, and some other places, were unfavourable to agriculture. Mr. Tenant found that seeds sown in earth, sprinkled with lime made from calcareous limestone, vegetated very well, and the lime operated favourably: but when sprinkled with an equal quantity of lime, made from a stone that contained two parts of magnesia to three of pure lime, they did not vegetate.

His experiments were made, evidently on *secondary* limestones containing magnesia; and the stratum of this kind of limestone he found superincumbent on the purer calcareous stone; and which in general he considers as alluvial limestone, in reference to the strata on which his experiments were made.

Judge Peters transmitted to me, nine different specimens of limestone from Chester county, numbered and named as follows:

No. 1 Holstein.	No. 5 Hughes's.
2 Coates's.	6 Dr. Gardener's
3 Yocum.	7 Barnet's,
4 Cleaver's.	8 Ballee's.
	9 Baker's.

Of these No. 7 is regarded as the strongest for building or for land, and No. 9 the weakest. The first four are strong lime, 5 and 6 of medium quality, and No. 8 nearly equal to No. 7: that is, according to their reputation in the neighbourhood.

Upon these limestones I have made experiments for the purpose of ascertaining their component parts, but chiefly as to the magnesian earth, they may hold.

It is not an easy problem to discover the most simple, the cheapest, and the most accurate method of separating magnesia from limestone and clay, (from lime and alumina.)

We have no good precipitant of magnesia: phosphoric acid requires combinations that make the results complicated, and drive us to calculation, which when I can, I would avoid.

The following methods have been used, to separate magnesia from a combined solution of lime and magnesia in the muriatic acid.

1st. Separate the lime by the oxalic acid. This is too expensive.

2ly. Precipitate the lime by saturated carbonat of potash, which in the cold throws down the carbonat of lime, and the residual liquor heated lets fall the carbonat of magnesia. This is a method recommended by Davy and Henry; but I have never been able by this method perfectly to keep separate the carbonats of these two earths.

3ly. Throw down the carbonat of lime by carbonat of ammonia: filter: then add to the muriat of magnesia containing carbonat of ammonia, phosphat of soda. The ammoniaco-phosphat of magnesia is precipitated; and 151 grains of this triple sult dried at 90° of Fahrenheit, answers to 100 grains of muriat of magnesia. Hence, if 20 grains of a mixed solution of the muriats of lime and

magnesia give 15,1 grains of ammoniaco-phosphat of magnesia, the mixture contains equal quantities of muriat of lime and magnesia. Or, 100 grains so dried are equal to 111 grains chrystallized, or 62,2 of dried sulphat of magnesia. But this seems to me below the average water of chrystallization in sulphat of magnesia, which contains nearly 50 per cent. 26 Nich. Journ. 274.

This process, is used by Dr. Henry, Dr. Wollaston, and I believe by Dr. Marcet.

4ly. The lime may be precipitated by oxalat of potash, and the muriat of magnesia, may be separated either by the filter or by alcohol: and precipitated either by hot carbonat of potash, or by ammoniaco-phosphat of soda. Or the alcohol or the acid may be driven off by exposure for an hour to red heat. Or, by sulphuric acid, the magnesia may be chrystallized under gentle evaporation into Epsom, or the bitter purging salt of magnesia.

5ly. The muriat of lime, may be precipitated into Gypsum, either by sulphuric acid, or by Glauber's or Epsom salt acidulated with a few drops of oil of vitriol.

6ly. The limestone containing magnesia, may be reduced into an impalpable powder, and treated with an equal weight of oil of vitriol, mixed with thrice its quantity of water. When the limestone is well powdered and sifted through fine muslin, and the superfluous acid driven off by heat, I believe this is as good a method as any.

In making the experiments of which I am about to give the result, I proceeded in two ways.

First. I took 100 grains of the stone powdered and sifted, and treated it with muriatic acid diluted with three waters by measure, stirring it frequently: after four hours, the supernatant liquor was poured off, and the undissolved residuum washed with an equal quantity of hot water as of the acid liquor, filtered, and dried in the heat of bout 160 Fah. and then weighed.

The solution, was then precipitated by a sufficient quantity of oil of vitriol cautiously added: it was left to stand after stirring till the gypsum had formed. Then filtered, and the separated gypsum put aside.

This second filtered solution, contained, muriat of magnesia, a small quantity of sulphat of magnesia, a small quantity of sulphat of lime, and alumina, with excess of acid. The alumina was thrown down in a dirty-coloured floculent precipitate, by the caution addition of carbonat of ammonia, and was separated by the

filter and washed, dried and weighed. The solution was then precipitated by hot carbonat of potash which threw down the magnesia and the lime; and filtered. This precipitate was re-dissolved in sulphuric acid, and left to stand. The sulphat of lime (generally about one sixth) separated spontaneously, fell down and was added to the first portion.

The whole of the magnesia was then thrown down by carbonat of potash, well washed, dried over a charcoal fire in the heat of about 160° and then weighed.

The sulphat of lime, or gypsum, was exposed in a crucible for 2 hours to a red heat, and the lime calculated on the proportion of 100 parts limestone to 130 of the anhydrous gypsum. A proportion, for which I will assign my reasons in a supplement to the present paper.

Secondly. I proceeded in another way.

I treated the finely powdered limestone with strong sulphuric acid (oil of vitriol of commerce); triturating them together in a glass mortar. I then added four times the quantity of water. The clear liquor was decanted from the sediment which was washed with another portion of water, and the liquors added together. The sediment (gypsum) was rendered anhydrous by exposure to a red heat in a crucible for 2 hours, and the limestone calculated on the proportion of 10 parts limestone to 13 of anhydrous gyps: deducting the silex previously found. The filtered solution to which the washings were added, was concentrated by evaporation, which occasioned a slight precipitate (about $\frac{1}{8}$th) of sulphat of lime: it was then treated with carbonat of ammonia for the alumina, and with carbonat of potash for the magnesia as before.

The component parts of the stones sent to me, were ascertained on the average of these two methods.

The limestones transmitted to me, bore evident marks of contiguity to primitive strata. The colouring matter was black hornblende, sometimes in streaks or veins, sometimes minutely divided and mixed with the limestone, giving the greyish tinge to the stone. The 9th specimen was intermixed with mica; the insoluble residuum of the four first specimens in dilute marine acid contained a small portion of matter, silky to the touch. I believe all the limestones connected with the range of primitive formations on the seaboard of our country from Boston to Virginia contain more or less of magnesia. They are in the immediate neighbourhood of the steatite and other magnesian strata, that envelope as a matrix, the

chromat of iron. I tried the specific gravity of three of them, which varied from 2,65 to 2,72 the usual range of common limestones.

No. 1. *Holstein :* Colour, greyish white : Fracture, uneven : Surface, common splintery : the stone seems to consist of minute lustrous chrystals: slightly fetid on being pounded. I obtained in 100 parts, silex 3, alumina 2, carbonat of magnesia 12. The rest was carbonat of lime or pure limestone. The traces of iron were evident with tincture of galls and prussiat of potash, but in no greater degree than might be attributed to the usual impurity of the acids of commerce. My muriatic acid was freed from the sulphuric, by muriat of Baryt.

No. 2. *Coates's.* Colour, greyish white: Fracture, uneven: Surface, fine splintery, consisting of minute sparkling chrystals. I obtained in 100 parts, of silex 3, alumina 2, carbonat of magnesia 14. The rest was pure limestone.

No. 3. *Yocum's.* Colour, greyish white streaked with blueish grey, being coloured with hornblende (amphibole.) Fracture uneven: Surface, splintery, small sparkling chrystals. I obtained in 100 parts, silex 4, alumina 2, carbonat of magnesia 14. The rest was pure limestone.

No. 4. *Cleaver's.* Colour, blueish grey : Fracture uneven in one direction, but splitting into laminæ of about ½ an inch thick in the other ; there was a very thin clay coloured sediment between the laminæ : Surface, opake, without lustre. I obtained from 100 parts, silex 4, alumina 6, carbonat of magnesia 14. The rest was pure limestone.

No. 5. *Hughes's.* Colour, white inclining to grey : Fracture uneven : Surface splintery, opake, void of lustre. I obtained from 100 parts, silex 5, alumina 2, carbonat of magnesia 12. The rest, pure limestone.

No. 6. *Dr. Gardener's.* Colour greyish, inclining to blueish white. Fracture uneven: Texture, a very fine, easily-pounded, sandy grit, consisting of minute lustry chrystals. I obtained from 100 parts, silex 2, alumina 0, carbonat of magnesia 16. The rest, pure limestone.

No. 7. *Barnet's.* Colour, white with a very slight clay coloured tinge: Fracture uneven: Surface, chrystallized lustry facets: Texture, saccharoid, the same as the saccharoid limestone on the York turnpike road about 10 miles from Baltimore. I obtained, silex 1, alumina 0, carbonat of magnesia 14. The rest, pure limestone.

No. 8. *Buller's.* Appearance like No. 7, only the facets of the chrystals much smaller. Silex 1, alumina 0, carbonat of magnesia 14, the rest limestone.

No. 9. *Baker's.* Colour ash-grey intermixed with brown mica, so as to bear the appearance of a mixture of pepper and salt: Small lustry chrystals. I obtained silex 36, undecomposed mica 4, alumina by precipitation 6, carbonat of magnesia 4. The rest limestone.

Hence it should seem, that the proportion of magnesia in these stones, is not so great as to produce any remarkable effect, either in agriculture, or as cements. The last (No. 9,) is doubtless the worst, as containing so large a proportion of siliceous sand, which on light soils is worse than useless.

Tenant's limestones, contained a much larger portion of magnesia, and the effect was therefore more evident. The greater proportion of limestone used in England than in this country, with the same effect, may arise not from the nature of the lime, but of the soil whereon it is put. It is there used in large proportion to strong loamy arable soils, and to swampy, spouty ground, that tends to produce sorrel. When it is used for the purpose of producing white clover, for which it seems to be a specific stimulus, it is not applied in greater proportion there than here, and merely as a top dressing. That is, so far as my observation and recollection enables me to speak on the subject. T. C.

On Sulphat of Lime, Plaister of Paris, or Gypsum, and the methods of ascertaining it.

There are two natural varieties of sulphat of lime, the common or *hydrous;* and the *anhydrous* containing no water of chrystallization.

The common plaister of Paris is made anhydrous by boiling from 4 to 6 hours in an iron pot: and it becomes a *cement*, by re-absorbing its water of chrystallization.

Common sulphat of lime, may be made anhydrous, by exposing it in a crucible in small quantities to a full red heat for an hour.

The carbonic acid in common limestone may be regarded as $44\frac{1}{2}$ per cent.

Smithson Tenant obtained 39 grains of calcined sulphat of lime by means of vitriolic acid, from 30 grains of carbonat of lime. This agrees with my own observation from repeated experiment.

Vauquelin, Berthier, and Thompson, compute the lime in calcined sulphat of lime at 42 per cent. Klaproth and Henry at 41 per cent. Chevenix 56,3 per cent.

Hence, according to Tenant, 77 parts of limestone will make 100 parts of *calcined gypsum.*

According to Vauquelin, Berthier, and Thompson, it will require 75,67 parts of limestone.

According to Klaproth and Henry, 73,87 parts of limestone will suffice for 100 of gypsum.

According to Chevenix it will require 101,4 parts of limestone. (2 Nich. Jour. 196.)

Hence also, taking the average of the experiments of Vauquelin, Berthier, Thompson, Klaproth and Henry, and considering the lime to be 41½ per cent. in anhydrous gyps, 100 grains of limestone ought to produce 135 grains of sulphat of lime; which according to Henry, 26 Nich. Journ. 278, it does produce at a low red heat.

Bucholz and Thompson make the common gyps to contain 24 per cent. of water of chrystallization: Bergman and Henry 22: taking 23 as the average, then the analysis of common gyps will be acid 44: lime 33: water 23 per cent. For my own part I never could expel more than 21½ parts of water, from 100 parts of gypsum.

The experiment of Mr. Chevenix cannot be reconciled with any of the rest.

Hence it is manifest that there is no accurate agreement among Chemists, either as to the proportion of lime in gypsum, or the proportion of water in that substance. This diversity is owing entirely to the varieties of temperature in which the gypsum when obtained by their experiments was dried.

On entering on the course of experiments to ascertain the component parts of the limestones sent to me by judge Peters, I found it convenient to institute a set of experiments on gypsum for myself.

Klaproth from 100 grains of pure carbonat of lime, procured 160 grains of chrystallized gypsum.

Henry and others at a low red heat procured 135 grains.

Tenant at a higher heat 130 grains.

I procured 150 grains of gypsum from 100 of pure limestone, when the gypsum after being carefully washed in a moderate proportion of water was dried for an hour on the top of a ten plate stove, on which I could just bear my hand. But when I calcined it for an hour in a full red heat, I procured from 100 grains of carbonat of lime, but 130 grains of gypsum.

I took a well characterized piece of compact gypsum from a ton that lay for sale in the street here; and reducing it to fine powder, I calcined it in a crucible in a *full* red heat for an hour. I drove off $21\frac{1}{2}$ parts: this occurred to me three times.

I took from a lump of the same gypsum (Nova Scotia, imported to Baltimore and thence sent to Carlisle) some of the semi-transparent chrystals of a vein that ran through the lump. Exposed to heat in the same manner, the result was the same.

Hence I conclude; that 100 parts of pure carbonat of lime, will yield 130 parts of anhydrous gypsum (from which the water has been expelled) and from 151 to 152 parts of gypsum as it is commonly found.

In the spring of 1809, I went into the Genesee country, and brought with me to Northumberland several specimens of gypsum which I had found there. I have since understood that Mr. Church of Angelica in that country, had previously discovered and used some gypsum, as a stucco.

The country adjoining the waters of the north east branch of Susquehanna, are now supplied with gypsum from the Genesee. This commerce began in 1811. A set of people in the neighbourhood of Pine creek in 1812, sold great quantities of common limestone for gypsum, and deceived many farmers, and injured many millstones by the deception. It may be worth while to give a few *characters of gypsum* that may prevent a similar imposition.

First. When a piece of stone is presented to you as gypsum, try to scratch it with your nail, and to chew it between your teeth. You may thus scratch and pulverize gypsum, but you cannot easily do so with limestone, which is much harder.

Secondly. Drop on it, a drop of spirit of salt, or of aqua fortis. If an effervescence, a bubbling, and extrication of air ensue, the stone is probably limestone; for no such effervescence takes place on a piece of gypsum, but the acid spreads evenly upon the surface as a drop of water would do. Now and then indeed, a specimen of gypsum may contain a small portion of limestone, but this does not occur often.

Thirdly. If the preceding tests do not give satisfaction, then take 100 grains of the stone: reduce it to a fine powder: grind up with it 250 grains of common pearl ash, boil them in a tin or earthen vessel with half a pint of water to dryness. Wash what remains by three separate affusions of half a pint of boiling water: dry the sediment at the bottom. If the stone be gypsum, that sediment will weigh 77 or 78 grains; it will have all the properties of common limestone reduced to powder, it will effervesce with, and totally dissolve in a mixture of one part of spirit of salt to two parts water added by degrees till the whole be dissolved. T. C.

Chicory. Succory. Chicorium Intubus.

Extract of a letter from Judge Peters to the Editor.

"In the life time of General Washington, many years ago, he "had frequent correspondence with the Scavans in agriculture, in "Europe. It became so burthensome to him, that at his request "I took it off his hands. I had much intercourse with several of "them on the subject of the chicorium intubus. Arthur Young, "was enthusiastic *for a time*, in favour of this plant. He has hot "and cold fits on most subjects. Both the General and myself "tried this plant as a grass, with no such wonderful effects as those "Mr. Young had pourtrayed. Yet we found to a certain point that "it was valuable. Having long given up my farm to tenants, I am "only a sort of chamber-counsel in husbandry. I reserve 20 or 30 "acres for amusement, and on this small scale continue to try every "thing I hear of, any wise likely to be useful. As a material for "*Coffee*, I have never known the *Succory*, as we call it, or *Chicory* "as it is called perhaps with more botanical correctness. The na- "tive succory I found in this part of the country, was a mean plant. "If without much trouble you could procure for me seed of *good* "native or foreign chicory, I will begin some experiments on its "uses as a substitute for Coffee. Inform me of the method of "treating it for this purpose. I am, &c. *Richard Peters.*'

The Chicory, is a species of Endive; wild Endive: the seeds of these plants are much alike.

In the state of Pennsylvania, though but in a few places, chicory or succory as the German settlers call it, has been cultivated as a substitute for coffee with much success. The plant is sown in beds either drilled or broad cast; and thinned out to about six or eight inches apart. In the beginning of winter they are taken

up, washed, and put into an oven after the bread is drawn. In this state they keep well. When wanted for use, they are again put into the oven after the bread is drawn, and dried till they assume a full brown colour. They are then ground or beaten in a mortar, and mixed with from one fourth to one half of their weight of West India coffee. I have repeatedly drank of this beverage without distinguishing it from common unmixed coffee. In Northumberland and the neighbourhood, and at Williamsport (Pennsylvania) this use of chicory is common. It would be improved, if in the last roasting, the chicory could be roasted with the coffee so as to imbibe the vapour of the latter. The chicory of itself is the best substitute hitherto known.

In England they use (or rather propose, for coffee is too dear there to be a common beverage) as substitutes for coffee, 1st. Roasted Barley. 2ly. The seeds of the yellow water flag, or flower de luce (Iris pseudacorus) 22 Nich. Journ. 70. 3ly. The ockra, which is also a fashionable substitute in the West India Islands. But the German establishments for the manufacture of chicory coffee, and what I know of it by my own experience, leads me to recommend in preference, this plant to all others.

Previous to the capture of Jena, by Buonaparte, there were upwards of two millions of pounds of chicory coffee, exported from that place and Brunswick to various parts of France and Germany.

But whatever may be the use of this plant as a substitute for coffee, it is not to be compared in point of importance to its use in agriculture, particularly as fodder for cattle of all kinds in cases of a dry spring, or summer. It is equally nutritious and more productive than Luzerne, without requiring half the attention.

The first notice I find of the agricultural use of this plant, is in the 6th. vol. of Young's annals of agriculture, p. 48, where Mr. A. Zappa of Milan, enumerates it as one of the favorite plants in the meadows of Lombardy. This was in 1786. In 1787, Arth. Young being at M. Crette De Palleuil's* near St. Dennis, was so struck with it, that he bought 10lbs. of the seed, and sowed it at Bradley, 10lbs. to the acre. In May 21, 1789, he cut it on a small patch, that yielded *at the rate* of upwards of 12 tons 11 cwt. of green fodder per acre, at a time when every other meadow was parched and dried up. On the 24th July he cut the same patch again, which yielded at the rate of 16 tons 4 cwt. of green food: on the 3d of

* The Life of this most useful citizen who died 30 Nov. 1799, may be found in 14 Month. Mag. p. 257.

December, he cut it again, and obtained at the rate of 9 tons 14 cwt. per acre; in all, 38 tons and 9 cwt. of grass. This, on losing three fourths in drying, would have yielded upwards of 9 tons of Hay.

But these experiments being made on a small scale, furnished no criterion for a regular course of husbandry, in which chicory should form a permanent part of the meadow crop; he proceeded therefore in sowing it, till in the spring of 1792, he had 14×60=74 acres, either entirely or partially sown with chicory. The other grasses he sowed with it, were the red clover, and timothy, rib grass, poa trivialis or common meadow grass, and these were sown with the chicory on the principle that as this grass does not tiller, the other accompanying grasses fill up the ground and make a full, close sward. It may be noted, that in England, chicory appears as one of the earliest spring grasses, being from 3 to 4 inches high on a poor soil on the 11th of May: but yet, not so early as the avena elatior the tall oat grass, or the rough cock's foot, dactylus glomeratus. By this time Young had ascertained, 1st. that though a perennial, it will not bear frequent seeding without being impoverished: and 2ly. that it is better to cut it after the first year at least 3 if not 4 times, in the course of the season. In this year he has registered the feeding of 58¾ acres of chicory alone, or with other grasses, by means of sheep. Indeed, all cattle, horses, oxen, sheep and swine eat it greedily.

This experiment appears to have turned out very satisfactorily, but it is too long to repeat here. The subsequent numbers of the annals of agriculture contain notices by the editor himself, though few by other persons. In the volume for 1799, I find the following note. "If the reader turns to vol. 28, p. 386, he will find an ac-
" count of chicory by Mr. Martin of Northampton: meeting him
" this year at the Duke of Bedford's sheep shearing, he informed
" me that in the present season he has nothing on his farm, no plant
" or crop whatever, that will keep half the stock which his chi-
" cory will, though it be four years old."

His account of the French husbandry of chicory may be found in the 2nd vol. of the tour to France p. 62.

In addition to this, I may add, that in the year 1793, Mr. Roscoe of Liverpool, walked with me to see Mr. Wakefield's Dairy farm about 1½ mile from the town.

Mr. Wakefield had sown in 1793 about 3 acres, and cut it 3 times in 12 weeks: the whole was given to 10 heavy working horses, who went through their common labour upon it without hay

or corn. He calculated to feed his dairy of 120 milch cows during the succeeding summer chiefly on chicory, and in the winter on potatoes steamed. He gave me 2lbs. of the seed, which I distributed partly to Mr. John Adlum then of Muncy, and partly to Mr. Samuel Wallis, but I believe they made no use of it.

His mode of steaming his potatoes is curious. A large iron pot is let down into a hole even with the surface of the ground. A fire place is made underneath, and a brick flue at the opposite end. Round the rim of the pot is a wooden kirb about 2 or 3 inches broad. When the water boils, a hogshead full of potatoes (well washed and scrubbed at a trough under the pump) is rolled over the boiler within the wooden kirb. The bottom of the hogshead is pierced full of holes. A loose cover is put on the top. The steam ascends through the holes in the bottom, and in half an hour, the potatoes are boiled. The hogshead is then rolled off and another rolled on. I think he had 3 iron boilers for the supply of his cattle with steamed potatoes. Potatoes were at that time worth about 2s 6d sterling the load of 240lb. washed, or 250 in the dirt. A bushel of potatoes will weigh about 72lb. The average crop of Lancashire and Cheshire, cannot be taken at less than 400 or 450 bushels per statute acre. This is effected by dint of manure laid on at the rate of 10L. sterling an acre, and accurate weeding, which the potatoe crop pays for, and brings the land in heart for 2 or 3 years.

In 1797, that promoter of British Agriculture the late Duke of Bedford, directed a poor field of brushy soil on his farm at Woburne, worth from 7 to 10s. an acre, to be sowed with chicory. The first year's produce supported seven Leicester sheep averaging 22lb. a quarter, per acre, for six months. His grace was of opinion that no other artificial grass on the same land would have equalled this.

Arthur Young says that the Chicorium Intubus grows wild in Suffolk and other parts of England. The Rev. Mr. Muhlenberg of Lancaster says it is a common plant or rather weed, about Lancaster. They both agree that in its wild state, it is not worth any thing. But by long course of cultivation the French, and from it, the English seed, is now a very valuable improvement on the wild succory. The Chicory I have seen growing about Northumberland and in Lycoming county, is certainly not equal to what I saw at Mr. Wakefield's in 1793: In 1797 and 1798 the seed sold in London for a dollar and 5s the lb. T. C.

Some observations on vegetation, and manures, by the Editor.

Agriculture. The art of selecting and raising to the best advantage, those vegetable substances that serve for the use of man.

It is not my intention to enter at large into the extensive theory of this first of arts, or to give a detailed account of practices adopted or recommended by the numerous writers on this prolific subject: but a few *general* observations hitherto seldom noticed in the connection now presented to the reader may furnish more accurate ideas than commonly prevail.

The theory of agriculture relates to I the properties of the plant itself. II. of the climate and soil in which it is placed. III. The mode of accelerating its growth and encreasing its size

Writers on agriculture, ignorant for the most part of the physiology of animals as well as vegetables, have usually considered and treated of plants as inanimate beings: they are not so.

Every plant is the production of an organized seed endued with the property of vegetable life, and of being acted upon by appropriate stimuli. This vegetable life is originally excited and subsequently continued by the application of what may be called *natural* stimuli, much in the same manner as in animals. Thus the pollen of the pointal received by the chive, and thence propagated to the seed vessel, impregnates the seed, and excites the action of the living fibre, which afterwards proceeds according to the laws of organization peculiar to each plant. This action is continually renewed by the application of vegetable food by means of which the germ is dilated till the plant arrives at its full growth. All this is perfectly analogous to the impregnation of the animal germ in the ovarium, and its subsequent growth to full age and size.

In animals, the muscular fibres have the property of contracting on being irritated. *Irritability* as it is called. So have vegetable fibres. The sensitiveplant, the hedasyrum, the dionæa muscipula of Carolina, the phenomena of plants growing in a dark place and turning to the light, are proofs of this, if not of voluntarity. The separated twigs of hedasyrum, are irritable, like a separated muscle. Mr. Howard has lately discovered the same property in the pollen, on the application of alcohol. (Trans. Linn. Society of London.)

Animals have feeling, perception, or *sensibility*, and the power of voluntary motion. So have plants.

The facts adduced by Percival, Smith, and Darwin, and the whole

class of phenomena relating to their search of food, and the propagation of their species seems to put this beyond reasonable doubt. To which may be added the habits and customs of the parasite plants.

Animals though perfect in all their parts, may be stinted in their growth by too small a quantity of food, and by other means; and this diminution will affect the size of their offspring. The case is precisely the same with plants. By plenty of food and favourable situations, animals may be encreased in size. So may vegetables. By breeding from selected couples of a large size, the size of the animal offspring is encreased. Hereon was founded the successful practice of the greatest cattle breeder in England, Mr. Bakewell of Ditchley; and the same set of experiments has been repeated with equal success on plants by Mr. Cooper of New Jersey. Mr. Bakewell encreased the flesh on particular bones of his cattle, and propagated this propensity. Mr. Cooper has in like manner propagated not merely encrease of size, but encrease of size in particular parts of the plant, and propensities to earlier vegetation.

In animals, appetite may be provoked, and digestion assisted, by the artificial stimuli, of what physicians call *Condiments*, salt, pepper, wine, acids, bitters, &c. Such also is the property of vegetables. Their hands, mouth, and stomach, are in the soil; and by the application of artificial stimuli, such as lime, common salt, alkalies, plaister of Paris, &c. their roots may be excited to want, to seek, to take in, and to digest more nutriment than they would otherwise use.

Animals may be surfeited with too much nourishment. So a plant will die if set in a mere dung-heap. Animals may be poisoned. So may plants. Every metallic combination for instance, except oxygenated and carbonated iron, and calx of manganese (and lead ?) in small quantities, being poisons to the vegetable.

By the artificial stimuli of condiments, animals may be excited too much, and indirect debility will ensue. So is it with plants. In like manner, excess of these artificial stimuli will take away their beneficial effects, as half a pint of wine may assist, when a bottle will injure digestion. Thus, from the experiments of Sir John Pringle, and Dr. Watson, (Bishop of Landaff) it appears that a small quantity of common salt is a septic to the animal fibre, and a manure to vegetables, while a large quantity, is the domestic antiseptic of cookery, and destroys vegetation altogether. So in the

experiments of Judge Peters, two bushels of gypsum will produce a luxuriant crop; 6 or 8 will prevent it.

In animals, when parts of muscular or other fibres, are weak, diseased and dying, artificial stimuli can be applied to excite an action in the living and healthy parts, by which the dead are separated and sloughed off. So in plants, the artificial stimulus of those substances which are not manures in the sense of affording nourishment to the plants, but only as exciting a stronger and more healthy action in the living fibre, will kill the weak and diseased roots, while they invigorate the more healthy. This is the mode of action (in part) of lime, gypsum, salt, &c. usually classed among manures, but which do not enter into the composition of the plant itself.

Animals are resolveable into gasses, lime and phosphoric acid. There is no peculiar animal earth. The phenomena of marine animals, the experiments of Vauquelin on the production of lime in the hen, and some other facts, make it probable, that the lime of the bones, as well as their phosphoric acid, is the product of animalization.

Vegetables are resolveable into gasses and fixed alkali by fire: by putrefaction their alkali is either decomposed, or escapes, for no fixed alkali is found on the incineration of vegetables which have undergone compleatly the putrefactive process. Both vegetables and animals contain in their fluids accidentally, unessential quantities of iron, manganese, and neutral salts. Thus the blood contains iron, albumen, mucilage, the serum, urine, uric and phosphoric acids with bases of lime, soda, volatile alkali. So in plants, nitre is found in borrage, in nettles, &c. and oxalates in some. Hence it appears, that the essentialy component parts of animals and vegetables consist chiefly of two or three gasses.

Again. Animal fibres are made from plants. So true is the scripture exclamation that all flesh is grass! An ox and a sheep are made up of vegetables, and so are we who devour them. Nothing is nourishment to an animal, but what was originally a vegetable. In like manner nothing is nourishment to a vegetable but what enters into the permanent composition of a vegetable. We find large plants grow in pure sand (Vanhelmont), in sand and clay, in common clay, in limestone, in limestone and sand, limestone and clay, and in all the combinations of these common earths, nay even in sulphur, in shot, in pounded glass, but we do not find that these earths or either of them, are any permanent and essen-

tial parts of the composition of a plant any more than of an animal. In a human body of 200lb. weight, we may find about the fourth or fifth of an oz. of common salt, and we may *perhaps* find in clover the same proportion of gypsum, but these are accidental parts of the composition.

More accurately. When a vegetable is decomposed by means of fire, in close vessels, we procure, 1st a considerable quantity of water. 2dly. Pyroligneous acid or an empyreumatic vinegar. 3dly. On the top of these and mixed with them, is a quantity of strong oily matter that smells of tar and smoke. 4thly. a great quantity of carburetted hydrogen gas, to wit about 50 quarts to the lb. avoirdupoise of fine saw dust. All woods, and (I believe) all vegetables, furnish it in some proportion. 5thly. A 5th or 6th in weight of charcoal, and nearly equal in bulk to the vegetable itself; of this about 90 parts in 100 are frequently pure carbon, when well burnt and freshly made and weighed. 6thly. Alkali: inland plants furnish the alkali of potash; marine plants generally furnish the alkali of soda. The alkali of potash obtainable from the green woods usually employed for the purpose, does not exceed one part in 16 or 1800parts. 7thly. earthy salts and iron, in minute and accidental proportions.

Now, The water, is hydrogen and oxygen.
The pyroligneous vinegar, is carbon, hydrogen and oxygen.
The oily matter is carbon and hydrogen.
The carburetted hydrogen, is carbon and hydrogen.
The charcoal is nearly pure carbon.
The alkali, is an oxyd of a metal.
The iron, or manganese may be accidental, but one or other is almost always found, though in minute proportions.

Some vegetables, as the farinaceous that contain gluten, and the succulent tetradynamious plants that contain albuminous matter, furnish also azot. So do mushrooms, trufles, and morells, which on distillation give out volatile alkali, the base of which is azot. But the vegetables that furnish azot, are exceptions to a general rule. Lime also in very small quantities, is frequently found in vegetables, but nothing tends to induce us to regard it, as other than an accidental substance.

The result is the same, when vegetable matter is decomposed in the moist way. Thus: let us take the case of a Distillery, and consider the process that goes on there. The bruised grain is mixed with water: then yeast, (that is, carbonic acid gas enveloped in mucilage) is put to it. The gas acts upon the grain, and decompo-

sition, and new compositions take place. Great quantities of carbonic acid gas are evolved: alcohol is formed: then vinegar, which is alcohol united to oxygen. What do these products amount to, but carbon and hydrogen, and the oxygen imbibed from the atmosphere? For every drop of vinegar is made at the expence of a particle of alcohol united to a particle of oxygen.

In the case of the decomposition of animal substances, whether in the dry, or the moist way, no acid appears: we get azot, a fetid animal oil, swimming at the top of a volatile alkaline liquor, and sometimes concrete volatile alkali, or carbonat of ammonia comes over. The retort contains an animal charcoal, consisting of azot, carbon loosely combined, the base of the prussic acid, and if bones be used, phosphat of lime.

In this case, the azot, the lime, and the phosphorus, seem to be new combinations, the result of animal organization modifying chemical affinity. There are many districts of Pennsylvania, perhaps the best pasture land in it, that do not contain a particle of limestone. Such for instance as a great part of the county of Luzerne and the beech country comprehended between the north east branch of Susquehanna, the New York state line, and the Delaware. There is no finer grass country; but limestone is rare throughout the greatest part of this space. A calf bred up there, will have *bones*, that is phosphat of lime: his flesh will yield *azot*, either by distillation, or by the nitric acid. Where does he get it? The soil contains none; the grass on which he feeds contains none, but the ox is chiefly composed of azot and phosphat of lime!

Hence it appears that about 99 parts out of a hundred of vegetable matter, consist of carbon and hydrogen of which the carbon far exceeds in quantity.

Hence also, the pabulum or food of vegetables, can only be carbon and hydrogen, or those substances which are easily decomposeable into carbon and hydrogen.

Hence animal matter is the best of manures, because, the carbon it contains is more easily disengaged, and the substance more easily decomposed than even putrescent vegetable matter. Hence it is that in steel furnaces and in case-hardening, animal charcoal is thought to aid the operation; the carbon of animal, being more easily separated, than the carbon of vegetable charcoal.

Hence we learn to distinguish, manures of *nourishment*, from manures of *stimulus*, and from *mechanical* manures; and we are taught that every vegetable and every animal substance when decomposed, furnishes pabulum to vegetables: and that every such substance

so decomposed is a manure of nourishment, and that nothing else is or can be. It may be taken for an axiom, that from man to a cabbage or a lichen, nothing can be converted into nutriment for the living fibre, but what has been a permanently component part of living fibre before.

Other properties of vegetables there are, *similar* (rather than analogous) to those of animals, which the necessary brevity of a short essay, will not permit to be detailed at length. It may be observed however, that plants like animals may be transplanted from one climate and soil to another, provided the difference be not very great, and care be taken to accustom them gradually to the change. Indeed, vegetables like animals will accustom *themselves* to the change in a generation or two, provided the difference be not above 8 or 10 degrees of latitude or of mean temperature. The range is not yet ascertained.

On the preceding properties of vegetables, and their analogies to animals, may all the agricultural doctrine of manures be well founded. These analogies have been remarked by others, but their application in this respect has not been heretofore sufficiently observed.

Animals *differ* from vegetables in having a more extended sphere of locomotion. The animal (cases nearly zoophytical, excepted) can move the whole of his body from one place to another ....a plant can only move its root-fibres and its branches. The *convolvuli*, and other parasite plants, are in some degree exceptions; but the general rule is, that the immovable centre of a plant's situation is the place where the germ falls, or the seed or plant is set with intent that it should remain. Hence the use of that kind of manuring which consists in the admixture of soils of various depths and adhesion, for the mechanical purpose of keeping the plant steady.

II. Of the climate and soil.

No experiments have been made to ascertain with precision the bounds of latitude or temperature which prohibit the naturalization of exotic plants. In France, YOUNG has marked the lines of the maize and the vine culture.....In this country maize grows tolerably well from lat. 42, and beyond it to Georgia. Wheat is not so good and productive south of Virginia, as in the middle states. The latitudes of cotton and rice, are not yet exactly ascertained. Coffee has not yet had a fair trial in our southern states, nor the sugar cane. Much indeed yet remains to be done in this

respect, and much is doing by the British government in the West Indies.

Agriculturists have many vague denominations of soil, such as clay, loamy, marly, sandy, limestone, limestone gravel, sandy gravel, stoney, poor light soil, rich black soil. These aretolerably descriptive in a general way; but as the theory of the art improves, we shall need more accuracy. Of the primitive earths, none need be noticed under this section, but silex or sand; argil or clay: and calx or lime. The others have never been yet found in sufficient quantity to produce any notable effect, except in the hurtful quality of magnesia when combined with lime, as 2 to 3 first noticed by Mr. TENNANT. It is evident that for the mechanical purpose of increasing or lessening adhesion, supporting the plant, and admitting its fibres to shoot more freely, clay, sand, and limestone are mutually manures to each other; acting mechanically by their mixture. Thus in Cheshire and Norfolk, in England, the clay and marl pits furnish an excellent and permanent manure to the sandy soil above; and assist moreover in retaining manure and imbibing moisture.

But it is not merely the mechanical mixture of soils that may be useful; for the experiments of M. D'ABRCET and M. FARONI have shewn us, that in the temperature of 100° of FAHR. different earths have different capacities for retaining moisture; so that by judicious admixtures, this valuable property in soils may be increased or diminished; and as none of the earths are found perfectly pure in soils, (clay, for instance, retaining 66 per cent. of sand without losing its distinctive character) tive character) a field is opened for ascertaining this property in different admixtures and combinations. For Mr. WEDGWOOD discovered that earths would chemically combine in the moist way.

Besides the tenacity of soils, and their capability of retaining moisture, their *depth* is also to be considered by the cultivator. Some plants have long tap-roots, such as rhubarb, liquorice, carrots, parsnips, madder, &c. These are evidently unfit for any soils, but of loose adhesion and of considerable depth. Equally preposterous would it be to use a soil like the Genesee flats, of 20 feet deep of light, rich mould, for grasses that spread upon the surface. Again, where soils are naturally sandy, dry, and arid and the climate warm, plants should be selected, whose roots penetrate deep and beyond the influence of atmostpheric evaporation. Thus, in this country as in the south of France, Lucerne, *(medica)* and

chicory *(cichorium intubus)* would be luxuriant where no other grass would grow.

III. I come now to consider the mode of accelerating the growth and increasing the size of plants.

This is done by *manures*. Hitherto, every substance added to soil or to the plant while growing, which effected, or was meant to effect these purposes, was called a manure. But, from what has been said, manure ought to be considered in at least four divisions. 1. Manures of nourishment. 2. Manures of stimulus. 3. Manures of moisture. 4. Mechanical manures.

Manures of nourishment. Five different theories have been started on this subject, the pabulum of vegetables.

1. Practical men have for ages discovered the use of dung in agriculture, and hence the common and oldest theory was, that the juices of decomposed animal and vegetable substances in the gross, were the chief pabulum of plants.

2. VANHELMONT's experiment suggested *water* as the pabulum, but although some plants will live, none will flourish in mere water....The French experiment of the decomposition of water, and the discovery of the excretion of oxygen, give countenance to the opinion that water, though not *the* pabulum, is decomposeable, and is a pabulum; furnishing hydrogen: and it is also a component part of the plant even as water. The curious experiments of M. Braconnot add strength to this opinion. It is not yet known whether plants can decompose azot, but I am strongly inclined to suspect this substance to be a compound, for we have no fact to shew that animals absorb it from the atmosphere.

3. Dr. HUNTER, of York, in his *Georgical Essays*, persuaded the world for some time, that oil was the pabulum of vegetables. But neither his theory nor his practice succeeded.

4. Dr. PRIESTLEY, who had more right to form theories and conjectures than any man living, (because he furnished more facts of extensive application in chemical philosophy than any other man,) suggested that *phlogiston* was the pabulum. Some experiments of ARTHUR YOUNG, made in consequence of this supposition, tend to support it. But though in all probability *inflammable gas* may be converted into nutriment to vegetables, yet it is far from being true, that this is the only gas which can. The gasses that escape from a dung-hill contain much carbon, azot, and ammonia, as well as various stimulating saline compounds. We know too, that electricity, and the galvanic fluid, seem to aid ve-

getation to a certain degree: but the action of these fluids is more satisfactorily accounted for, on the doctrine of stimulus, than of pabulum. That oxygen is not nutriment, is clear, from its being an excretion of plants in a healthy state, and in vigorous action, under the influence of the sun, as Dr. PRIESTLEY, and afterwards M. INGENHOUZ discovered. Hence, although fluid manures may contain the elements of phlogiston, or the combinations of phlogiston, this latter cannot of itself be taken as the only food of plants. Both plants and animals are resolvable into gasses of which phlogiston may be a part, but there is something else which feeds and dilates the muscles of animals, and the leaves of trees, for they furnish something else.

5. Dissatisfied with former theories, Mr. KIRWAN has proposed *carbon* or charcoal as the food of plants; and declares his opinion that if charcoal could be rendered soluble in water it would be the most efficacious manure. It is true, that charcoal and caruretted hydrogen, are found in the incineration of all undecomposed vegetables, but they contain also alkali, oxygen, and nitrogen, &c.; nor is there any fact to prove that charcoal (or the oxyde of carbon) is either soluble in any liquid, or taken up as charcoal by any vegetable, or decomposed by any natural process; soot as a top dressing is a tolerable manure in England, but its use may be accounted for from the saline substances it contains. From every fact hitherto known, the pabulum of vegetables, appears to be exhibited to plants generally in the form of a *liquid.* Hence, whatever theory of ingenious speculators be adopted as the simple and homogeneous pabulum of vegetable bodies in a living state, the old theory and the old practice must, and ought to prevail, namely, that the only manure of nourishment to be depended on, is dung, *(i. e.) decomposed animal and vegetable substances*; which contains within itself every substance that theory has hitherto assigned as the food of plants, ready to be afforded gradually, by the continual decomposition of the various compounds which the dung contains: and although it may be of use by dung-heaps to aid this decomposition, yet even in an undecomposed, or partially decomposed state, this gradual decomposition amounts in the end to the same thing. This is applicable to ground bone, woollen rags, horn shavings, &c. All the difference is that *time is gained* by the artificial and complete decomposition of these substances.

Manures of stimulus. Whatever accelerates the growth, or encreases the size of plants, and does not actually enter into the com-

position and substance of the vegetable, can only be considered as a manure, by stimulating the healthy fibre of the plant, by destroying the dead and decaying fibres, and by assisting the decomposition of undecomposed animal and vegetable substances dispersed through the soil. It is thus that *gypsum* or plaister of Paris acts, being the most efficacious septic among the neutral saline substances. Of these manures of stimulus, none are as yet in common use, but lime, gypsum, and common salt.

Lime, is limestone deprived of its water and carbonic acid amounting to 44 per cent. by fire. In this state, its stimulating powers are obviously much greater, than in its natural and neutral state of limestone. But even pounded limestone is a promoter of vegetation mechanically, on clayey and sandy lands; and this earth appears to be a specific stimulus to white clover, and perhaps to the potatoe. Hereto may be referred the rubbish of old buildings, and marl, which is clay about one half of limestone.

Common Salt. This, until the duty of two thousand per cent. in England, was a very common manure in Cheshire; the facts relating to it, in this point of view, are collected in WATSON'S *chemical essays*. In this country, Gypsum is much cheaper.

Gypsum, plaister of Paris, *vitriolated lime*, or *sulphat* of lime. This has not been certainly found in any plant, but by M. MODEL, accidentally, in rhubarb, (*Journ. de phys.* vol. 6. p. 14,) even this I suspect to be a fallacy; for the characters of gypsum were not then well ascertained. About two bushels per acre to clover or corn seem to be a full quantity. It attracts the moisture from the air, and dissolves gradually when strewed on the ground. It is brought here from France and the bay of Fundy, and has also been lately found in New-Hampshire, and on lake Erie. There is also some in Maryland on the Chesapeake, about one hundred miles below Baltimore, and throughout the Genesee country, and on the waters of the Chippawa. As it is not a component part of any plant, either in whole, or in its own component parts, it cannot act upon healthy vegetables but as a stimulus, and upon diseased and dead ones, by its septic power. Experiments remain to be tried as to other manures of this description.

Gypsum particularly deserves attention, considering that it has effected almost a complete revolution in the agriculture of Pennsylvania. Many thousand acres of land hitherto barren, have been converted into excellent pasture ground, by its surprising influence. Even the products of land, tolerably good, have been in some in-

stances doubled by using it. The theory of its action was not understood. Judge PETERS of Philadelphia, who first collected the opinions of our farmers, on the subject of the gypsum as a manure, ventured to suggest, that the vitriolic acid was the fertilizing principle of this manure: But Mr. Priestley of Northumberland, has given this opinion a fair trial, both by means of sulphur, and of sulphuric acid, in all proportions, without the slightest appearance of success. We shall have therefore as I think, to recur to the theory first advanced by myself in the year 1793, that it acts as a septic to dead fibres, and as a stimulus to living ones.

Manures of moisture and Mechanical manures. Their action in giving *depth* by new addition; in giving *tenacity* by mixture, as clay with sand, or *vice versa*....in giving *capacity to retain moisture*, on the principles suggested by the experiments of FABRONI and D'ARCET, is too obvious to require further elucidation.

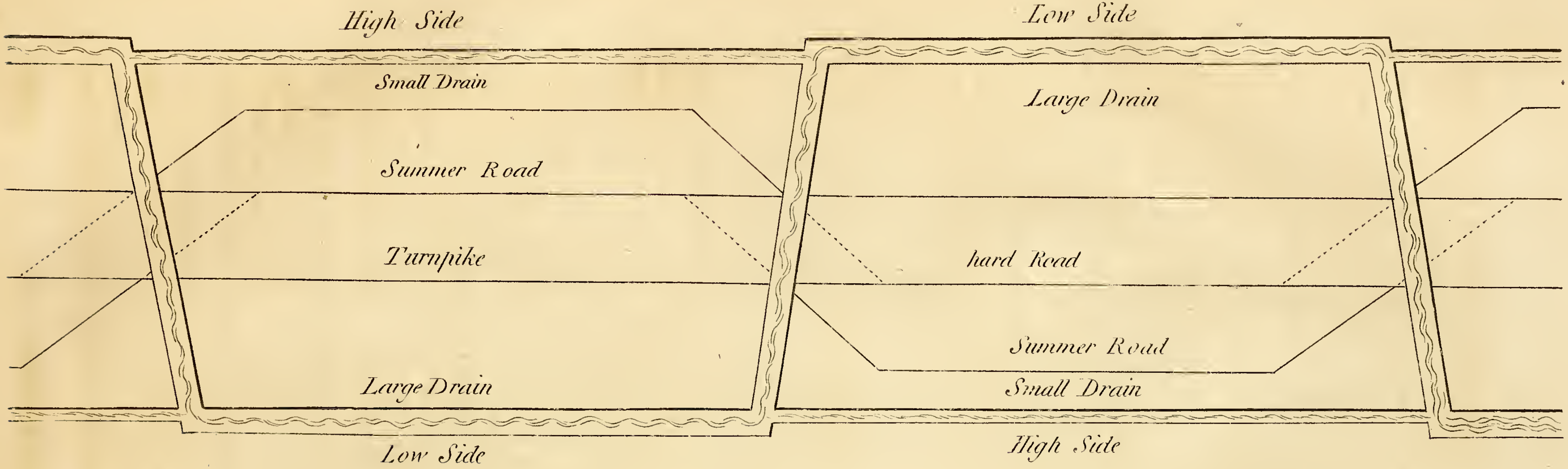
Such are the ideas that occur to me as throwing some light on the theory of this complicated and most important subject, and suggesting the *rationale* of the application of manures, in cases not hitherto well understood. T. C.

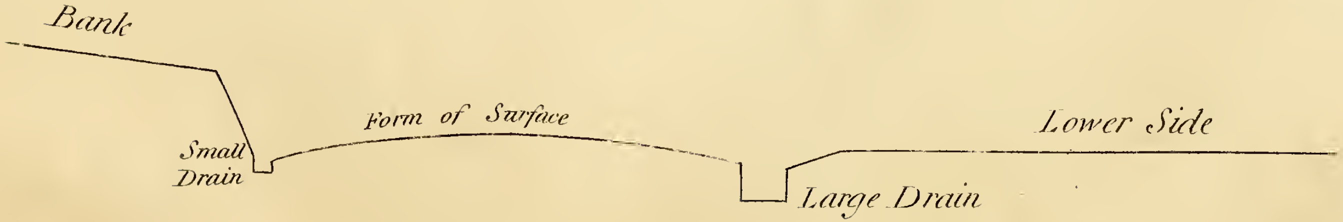
TURNPIKE ROADS.

To the Editor of the Emporium.

If turnpike roads and their drains, were to be formed at first according to the drawings, (See Plate) making the summer road to cross the paved road at every change of the surface of the country, so as to keep the summer road always on the highest side, with a small drain along side of it, (though it may do without any, as it has but little water to carry off) and to keep the large drain on the lower side, crossing at every change of surface of the country, until it can be let entirely off from the road—In such case, summer roads could be kept good at a small expence, as they would never be washed with the main body of water. The drains on the lower side could be kept from washing, by throwing in stones. But where an attempt is made to keep up a summer road on both sides, both become drains for the water, and in a short time both become inevitably lost; for a drain makes a bad road.

It is better to have one good summer road to cross the paved road often, than to have none at all. The summer road thus ma-


High Side
Low Side
Small Drain
Large Drain
Summer Road
Turnpike
hard Road
Summer Road
Large Drain
Small Drain
Low Side
High Side


Bank
Form of Surface
Lower Side
Small Drain
Large Drain

naged will be much the cheapest, for earth cannot be changed into any thing else by travelling on it, whereas the stone pavement is continually changing into earth, and requires expensive repairs. By such an improvement as is here suggested, many thousand dollars might be saved to stockholders. The summer road on the Lancaster Turnpike (and on others also) is already almost ruined for want of necessary precautions.

While on this subject, I beg to observe, that on my travels I see it frequent in opening new roads, to clear the lower side first for the carriages, and to allow the water to run along the down hill rut: thus the road soon becomes dangerous, and repairing it expensive: whereas if the passage for carriages was first opened on the upper side of the scite of the road, and the water confined to run along the up-hill rut, until it would be conveyed away, the road would ever after be kept in repair, for not more than one tenth part of the expence otherwise incurred. If you think the above worthy a place in your Emporium from one of your subscribers, it is at your disposal. I am &c. O. E.

I shall always think the communications of this correspondent worthy a place in the Emporium. To the preceding obvious and sensible remarks, I had intended to have added my notions of the chief cause of the destruction and want of profit of turnpike roads. I am persuaded, that carriage can be cheaper performed with 3 horses to a team than with four: cheaper with two than with three: and cheapest by means of single horse carts. I have not room in this number to insert the facts that induce me to think so, but I will collect them for the next. No turnpike can stand the wear and tear of five horse waggons, and be profitable to the stock holders. T. C.

NOTICE TO CORRESPONDENTS.

Some of the subscribers to the Emporium, have expressed apprehensions lest it should become a *political* publication: others have expressed disapprobation at the editor having supported the opinion, that manufactures should be encouraged at the expence of commerce.

As to politics: I hope there is no subscriber to the Emporium incapable of distinguishing between the petty discussions of party politics, and the great questions of political economy! If there be,

explanation would be useless to him. Whatever my politics may be, *I have none in this work.* As to the questions of political economy—what are the principles of public action (under whatever rulers, or whatever form of government) that lead most directly and permanently, to national wealth and national power—and are most consistent with national security and national prosperity—I shall continue to discuss them. They have been for some years, and still are under discussion among the ablest statesmen, and the best informed writers of Europe, and they are still unsettled. In this country, they were never touched, until my essay of 1799, and a brief view of the expedience of protecting foreign commerce, published soon after, by Dr. Priestley. At that time we were alone in our views of the subject. At present I am fully persuaded, that a decided majority of the literati of Great Britain who have turned their attention to these questions, are with us. In this country, the topics have been too little discussed, to allow any public sentiment to have been formed. The popular opinions—prevalent among those who have not read or thought much on the subject, are greatly adverse here, to what I think a correct system: but who is it that says they ought not to be discussed? can he be a friend to science, or a friend to his country? Ganilh's book, evidently published in opposition to Montgaillard's, has been reviewed with much encomium in the best of our miscellanies, the Port-folio, and with much laboured panegyric in Mr. Walsh's Review. What, is it a crime to dissent from their opinions?

The present series of the Emporium, professes to give, a connected set of essays on the leading manufactures of Europe likely to be of advantage in this country, taking them up one by one. But as all readers cannot feel interested in any one manufacture (unless men of general science) it is proposed to fill up at least a third of the work with miscellaneous essays. I greatly doubt whether I can make this an entertaining work. I fear I want qualifications: still less can I undertake, that all the opinions I may advance, shall meet with the full assent and approbation of all my readers. But this I can promise, that when I have gone through my twelve month's editorship of this work, it shall not be thrown aside, or torn up for waste paper. Those who have it will keep it, or I shall not answer my own expectations.

But the very design and intent of the Emporium, is, to give information on those manufactures which it is worth while to attempt in this country; every such manufacture, if it succeed, will take

away from the necessity of European importation. Those who think we ought to depend on Great Britain, for all our necessary comforts and luxuries, and raise nothing, and export nothing, but raw materials for British traders to work up and sell to us in a new form, will doubtless be the advocates of foreign commerce, and of all its concomitants: they will not approve of such a work as this, or wish success to any home manufacture, which will so far supercede the necessity of foreign importation. If readers of this description disapprove of the principles advanced in this work, I cannot help it: but most assuredly, a work that professes to aid the exertions of *home* trade, may without impropriety be permitted to suggest, that the benefits of *foreign* trade have been overrated; and allowed to state the facts and arguments that support such an opinion.

But the questions of political economy are really of so much national importance—they require and imply so much important fact to elucidate them—they are here so new—and every where so unsettled, that I feel ashamed of this apology. I shall be glad to receive condensed and well-considered replies to my own opinions. I have been collecting, some statistical and financial facts relative to Great Britain, France and this country, which I shall give in the next number.

I have read the first volume of Mr. *James Cutbush's* manual of chemistry, but I have not yet seen the second. There are some slight inaccuracies in the first, but it is a useful compendium; containing as much fact in as small a compass, with as little unnecessary matter, as any compilation I have seen for some time. I shall be glad of an opportunity of expressing myself as favourably of the second volume; which I dare say I shall be enabled to do very truly.

I have read the first part of a treatise on distilling, by Mr. *Harrison Hall*, of Philadelphia. If a few pages of chemical disquisition were omitted, and some practical directions given on the use of the hydrometer, it would be the *best* book I have seen on the subject. Indeed I consider it such as it is. It supercedes a great deal of what I had to say on this manufacture, but I can make some additions when the proper time comes.

I have received the description of Dr. Allison's machine for spinning wool, which shall have a place in the next number of the Emporium.

PHILADELPHIA, June 16, 1813.

DEAR SIR,

I have to express to you my thanks for the honourable mention you have made of my late exertions in the first number of your Emporium. Perhaps I could have wished, if you will excuse the observation, that the article had been a little more accurate. I have rendered platina malleable, which is a chemical process, but to work it up afterwards into spoons, &c. &c. is the business of artists, and mechanics. Our wags will say, "so the Dr. has turned spoon-maker at last," and they will have your word for it.

You also mention as a general, and apparently steady thing, that the specific gravity of my platina is 19.7—which happened to be the specific gravity of the *ill hammered* specimen you took with you. It generally weighs 21.5, and I have had several pieces of a specific gravity of 22.5. I must repeat on this occasion, that great specific gravity is not absolutely a proof of purity. A piece of pure platina of 19.5 may be hammered into a specific gravity of 23. and a less pure, but better hammered, that is compacter piece, may exceed in specific gravity a piece more pure.—We even know that the specific gravity of brass is greater than that of pure copper, though the specific gravity of zinc is inferior to that of copper; which proves that greatest density, and compactness of a substance—on which its specific gravity depends, does not necessarily imply its greatest purity.

As the article stands it gives the impression, that I only do what Mr. Cloud did before, but better. The fact however is, that Mr. Cloud, whose merits I well know and fully acknowledge—does not seem to have intended more than to produce a cabinet piece of the greatest possible purity and specific gravity, and he has done so: but I have first rendered platina malleable in this country, by means of a process, which admits being executed on a *large* scale, and which, I hope, will become beneficial to the arts, and to society.—Pieces have been made of the weight of two pounds, and upwards. Sheets have been rolled of thirteen inches square, and vessels of platina are now making, and in preparation, which will hold from twenty to thirty gallons.

The method I use is not the one you describe, and which could not be executed in the large way with safety, accuracy and dispatch. I have found hints of it in European publications, but I believe I

have considerably improved it.—You shall have a full account of it after some time, together with some experiments and observations on Platina, which, perhaps, you will not find uninteresting. I am no secret monger; (as you say manufacturers always are) but, since no body would choose to refund me the by no means small expences I have incurred in unsuccessful trials, it would perhaps be carying liberality too far to enable others at once to place themselves on my shoulders.

Many manufacturers, who have improved their processes, I think might plead the same observation in justification of their conduct, when desirous to keep their knowledge rather to themselves, or to impart it only to their children, than give it to the world at large. The patent law seems to sanction the principle that they should benefit by their labours. Why then should a term of reproach attach to individuals proceeding on the same ground ?

I have also succeeded in giving the metallic lustre to Pottery by means of Platina, the shades of which may be varied at pleasure, and some other applications of malleable Platina in the arts, are contemplated, of which you shall be informed as soon as their usefulness has been practically ascertained.

Political economy being my favourite science, I have read with particular attention, and interest, the pages relating to it in the first number of your Emporium, and it is with some regret that I perceive you have adopted, and endeavour to give currency to, a train of ideas, in my opinion erroneous, and the prevalence of which with too many, has already produced a vast deal of mischief. That they are both erroneous, and pregnant with evil, appears to me, after much, and repeated reflection, so unquestionably true, that I should not despair, in fair and liberal discussion, to convince Adam Smith himself of it, whom, I know, you have in many points on your side.

If, as a lover of truth, you will receive in a friendly manner, and give a place to in your next number, a few observations addressed to you, as such, on this subject, I shall forthwith commit them to paper, and I intend in this case to examine every position in your political arithmetic together with the arguments intended to support them.

An elementary *popular* treatise on political economy is a work which I conceive much wanted in this country, which I contemplated to write, and in which I have made no inconsiderable pro-

gress. But circumstances have obliged me to defer the full execution of the task to a more propitious moment. I remain, &c.

Thomas Cooper, Esq. Carlisle. E. BOLLMAN.

Upon this letter I have to remark;

That I am well aware of the fact, that the specific gravity of metals is encreased by hammering: but I doubt whether hammering alone will bring platina from 19,5 to 23, though I know that mercury is encreased by congelation from 13,5 to 15,6.

I have not ventured to say that the process I describe, is the same with Dr. Bollman's. I understand it to be the process hitherto commonly used in France and England. Achard's method with arsenic I have tried; but heat alone will not drive off the arsenic. Whenever Dr. Bollman finds it convenient to publish his process, I shall be very glad to make the Emporium the mean of communication.

I have said, manufacturers are secret-mongers. They are so; and they have a right to be so, if they think fit. I know of no obligation that calls upon them to disclose those secrets upon which their subsistence may depend. When they conceal, and make secrets of the common and usual processes of their manufacture, they do not act liberally: when they conceal processes peculiar to themselves, or not generally known, they exercise a caution, which may frequently be a duty. It is no term of reproach. The public are obliged to those who communicate knowledge of any kind; and every man who has lived long, and much in the world, and who has observed much, has much to communicate that the public will be the wiser for knowing; but there is no obligation on him to do so.

Dr. Bollman is fearful lest the wags should say he has turned spoon-maker. What! was not Prince Rupert a manufacturer—the Marquis of Worcester an engineer—the Duke of Bridgewater a canal-digger—the Duke of Norfolk and Lord Dundonnald manufacturers of coak and coal tar? Was not Sir Richard Arkwright a cotton spinner—Wedgwood and Bentley, potters? Are not Boulton and Watt spoon-makers? Does not Dr. Wollaston manufacture platina spoons? Tell me the men of Europe of whom their country has more reason to be proud, than Watt and Boulton and Wollaston? Lord Loughborough was right, when he said in debate, that weighed in the balances against such men as Boulton and Watt, Sir Richard Arkwright, the duke of Bridgewater and Wedgewood and Bentley, the Lords and the Commons would kick the beam. Dr. Bollman need not be ashamed of company in all respects so truly honourable. I should be glad to have discovered, as Dr. Bollman appears to have done, a method of manufacturing platina easily and cheaply into spoons or any other article of use or ornament, from the boiler of a steam engine to the spoon of a galvanic, or the crucible of an analytical chemist.

Dr. Bollman differs from me, in my notions of political economy: I am glad of it. I shall have an antagonist worth contending with. Whenever Dr. Bollman will send me his communications on this or any other subject, they shall be treated with the attention his talents have a right to claim. T. C.

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STEEL.

(Continued from page 284.)

The third kind of Steel, or 3dly. CAST STEEL.

In cast iron, the carbon used, has never completely and uniformly metallized all the iron by uniting with the oxygen which gave it the form of an ore: also, the iron is in some parts united to carbon not merely to saturation, but beyond it; and not merely chemically, but mechanically. Iron may be greatly supersaturated or overloaded with carbon, as in the case of plumbago (Black-lead,) and in the smooth black-lead surface of kishy cast iron.

But in *steel*, the carbon seems chemically united to iron, and to a certain point encreases its fusibility; cast steel then, is a chemical combination of blistered steel, with a still greater proportion of carbon; which is communicated to it, by fusing the blistered steel, either in contact with charcoal, or with limestone and bottle glass. I have already observed that 100 grains of chalk or pure limestone will yield 44 or 44_2 grains of carbonic acid gas; which 44 grains of gas, contain somewhat better than $12\frac{1}{2}$ grains of pure charcoal or carbon.

These remarks will explain the following report of Guyton Morveau to the National Institute of July 4, 1798, on Clouet's method of making steel.

Account of the Experiments of Citizen Clouet, on the different states of Iron, and its conversion into Cast-steel.*

The learned reporter begins his account, by giving an historical sketch of the scientific and correct information we possess, respecting the art of steel-making. He states, that from the time when the labours of Reaumur had enlightened the practice of making natural steel, and steel by cementation, the theory remained stationary, notwithstanding the numerous and valuable experiments of Bergman, Rinmann, Priestley, &c. until the appearance of the excellent memoir of Vandermonde, Berthollet, and Monge, in the Memoirs of the Academy of Sciences for 1786. That the English, who had long supplied the European market with steel of cementation, remained also in the exclusive possession of the article known by the name of cast-steel, which, though confined to certain fine works†, is, nevertheless, a very valuable branch of national industry; that various experiments have been made with success, on a confined scale, in France, to imitate this product, since the time when Jars published an account of the method used at Sheffield; but that from a want of precision in the narrations of these processes, and the difference which is, with justice, considered to subsist between the experiments of the laboratory, and those of the manufacturer in his extensive operations, the art of making cast-steel was considered, by the most eminent French chemists, as very far from being publicly known: and Vandermonde, Monge, and Berthollet, notwithstanding their acquaintance with these facts, thought fit to declare,

* From the report of Citizen Guyton, made to the National Institute of France, on 16th Messidor in the year VI. (July 4, 1798) inserted in the Annales de Chimie, XXVIII. 19.

† It is used in a great variety of common tools and works in England.

in the public instructions drawn up by order of the committees of safety, that they could offer nothing but conjectures on the subject*. In this situation was the knowledge of the chemists and manufacturers of France, when Citizen Clouet resumed his experiments on a larger scale at the house of the Conservatory of Arts, and the mineralogical school at Paris, on the fusion of various kinds of steel, and the immediate conversion of iron into cast-steel.

On this subject, the author delivered a memoir to the Institute of France, which forms the subject of Guyton's report. He first treats of the combinations of iron and charcoal. One thirty-second part of charcoal is sufficient, as he affirms, to convert the iron into steel; one-sixth part of the weight of the iron affords a steel which is more fusible, but still malleable; and, after this term, it becomes nearer to the state of cast-iron, and no longer possesses enough of tenacity. By augmenting the dose of charcoal the fusibility is increased; and, at last, it acquires the state of grey cast-iron.

The particular cast-iron, which results from the combination of iron and glass, forms the second object upon which the attention of Citizen Clouet was fixed. The glass enters but in a small quantity into this compound, notwithstanding which, the properties of the mass are changed. This iron, though very soft to the file, if heated merely to cherry red, flies in pieces under the hammer: the cast ingot contracts greatly in cooling; and when, by careful management, it has been made into bars, the operation of hardening gives them the grain of steel, and renders them brittle, without adding to their hardness.

Charcoal in powder, added to the glass, changes the result, and increases the fusibility; but the nature of the product is greatly influenced by the dose of these ingre-

* Nichols. Phil. Journal II. 102.

dients. From one-30th to one-20th part of the iron, affords steel capable of a high degree of hardness, which may be forged at a low red heat, and has all the properties of cast-steel. If more charcoal be employed, the products resemble those of the smelting-furnace.

The attraction of iron for carbon, continues Citizen Clouet, is such, that at a very high temperature, it will take it even from oxygen. He proves this by the following experiments: Let iron, in small pieces, be put into a crucible with a mixture of equal parts of carbonate of lime and clay; let the heat be urged to the degree necessary to weld iron, and kept at that elevation for an hour, or more, according to the size of the crucible: the metal being then poured into an ingot mould, will prove to be steel of the same quality as cast-steel.

The oxydes of iron are equally susceptible of passing through the states of soft iron, steel, and fusible or cast-iron, according to the proportions of coal made use of. The black oxyde of iron, of which the state appears to be the most constant, becomes iron when heated in the crucible with an equal bulk of charcoal powder: a double quantity affords steel: a progressive augmentation, imparts the characters of the white and the grey cast-iron.

Lastly, Citizen Clouet observed the same transitions dependant on the respective quantities, by heating cast-iron, and the oxyde of iron; cast-iron and forged-iron; the oxyde of iron and iron; the oxyde of iron and steel. No more than one-fifth of cast-iron is necessary to convert bar-iron into steel.

Iron and its oxyde do not intimately unite together. The black oxyde, mixed with half the quantity of charcoal which would be necessary for its reduction, affords iron, which is soft, possessing little tenacity, of a black colour, and indistinct fracture.

One-sixth of oxyde, restores common steel to the state

of iron, by heating them together in the forge, or in the way of cementation.

At the end of his memoir, Citizen Clouet has given observations on the manner of producing cast-steel, and the furnaces proper for this effect.

He determines the nature of the fluxes, the degree of heat, the quality of the crucibles, the precautions for casting the ingot, the method of forging this kind of steel, the processes to be followed in experiments at the forge upon two kilogrammes of the materials, and the proportions to be given to a reverberatory furnace capable of heating four crucibles, each containing 12 or 13 kilogrammes of steel (about 28 pounds avoirdupois each crucible).

He remarks, that the mere ingredients of saline glass cannot be directly used in this process; that glasses, which are too fusible, render the steel difficult to forge; that steel, kept for a long time in fusion, takes up more glass than is proper; and lastly, that the melted matter must be stirred, and the glass carefully taken off before casting, in order to prevent its mixing with the steel.

The Commissaries of the Institute proceeded to repeat and verify the experiments of Citizen Clouet. These operations, which are related at length, were as follows. 1. Six hectogrammes (about 21 oz. avoirdupois) of filings of farrier's nails, and four of a mixture of equal parts of white marble, or carbonate of lime, and baked clay of an Hessian crucible, both reduced to powder, were well blended together, and exposed to the heat of a forge-furnace urged by three bellows-pipes for an hour and a half. The crucible failed at the first experiment; but, on repetition, a bar of steel was afforded. 2. Upon making the experiment with Macquer's furnace, the fusion was not complete, though the fire had been urged to 151° of Wedgwood. 3. In another excellent wind-furnace, 367 grammes (about 13 oz. avoirdupois) of small-drawn iron

nails, and 245 grammes (about 8½ oz. avoirdupois) of a mixture of carbonate of lime and baked clay, were exposed to strong heat for an hour, when the fusion was judged to be complete; and after removing the vitreous matter the ingot was poured out. From the effect produced on two pyrometric pieces, it was judged that the steel had undergone a heat of 150 degrees. This steel had all the properties of cast-steel, and was made into razors by citizen Lepetitoualle, who found it of a good quality, easy to be worked, and capable of bearing a comparison with the cast-steel marked *Marshal* and *B. Huntsman.*

Upon these facts, the reporter observes, that since iron does not become steel but by taking up about 0,2013 of its weight of carbon*, and in the present process it exists only in the form of carbonic acid, this acid must consequently be decomposed; which happens, as the reporter observes, by means of a combination between its principles respectively and certain adequate portions of the iron, that is to say, the oxygen of the acid combines with part of the iron, and forms an oxyde with which the vitreous flux becomes charged, and the carbon combines with the rest of the iron, and forms steel. Hence it may be inferred, that this new process must be attended with a loss of so much more consequence, as it is necessary to use iron of the best quality for making steel. But, on this head, the reporter takes notice that the loss in the experiment with the wind-furnace was not quite one-twelfth part; and, in another experiment, by Vauquelin, the loss was less than one twenty-second part; a loss, which he observes, will be well repaid by the increased value of the

* This quantity (upwards of one-fifth) so much exceeds any addition which iron is stated to gain by conversion into steel, that I suppose it to be 0,2013 in the centenary or hundred parts of iron. Iron is reckoned to gain about a little more than half a pound in the hundred weight by cementation.—3 Nich. Jour. quto. 134.

product, and may reasonably be expected to be still less in operations on a large scale. He thinks, moreover, that this new method may probably turn out of high value for producing steel of uniform quality with regard to the dose of carbon. For he thinks that this quantity, or proportion is likely to be determined by the equilibrium of the forces of affinity which cause the decomposition of the carbonic acid. Or, in other words, if we suppose an indefinite quantity of carbonic acid to be presented at an elevated temperature to a mass of iron not greater than could be converted by the dose of carbon contained in that acid, the iron will form two combinations, the oxyde and the steel; and it is conceived that the equilibrium between the attraction which tends to preserve the union of principles in carbonic acid, and those which are exerted between the iron and those principles will prove to be such that the carburet of iron will be formed precisely in those proportions which constitute good cast-steel. This subject, which certainly shews the acuteness of Citizen Guyton with regard to the doctrines of chemical attraction, must be decided by the test of experiment.

The report is concluded with a summary of the facts and observations it contains, together with an inference, that the immediate conversion of iron into steel, without using charcoal, is a great and valuable discovery with regard to the increase of national industry; that there is no doubt but the process will succeed in the large way, and that Citizen Clouet is entitled to a public recompence for his liberal, and unreserved communications.

That all the facts are of high value to science, and that the observation respecting the combination of vitreous matter with iron, as well as that which shews that carbonic acid can produce the steel conversion, are new and important, cannot be questioned; but whether the use of carbonate of lime and clay, which is attended with some

loss, may be preferable to vitreous flux and coal, which afford some small additional weight, is not yet as it should appear, decided by the actual operations."

These experiments of Clouet, were repeated by Mushet; who found that no mixture of limestone and clay, no fusion with lime alone, or with glass alone, in a *common* crucible, would convert iron into steel; though the properties of the iron were in some degree altered: but when the fusion took place in a *black-lead* crucible, steel was uniformly produced. Hence it may be reasonably presumed, that the carbon was furnished, not by the decomposed carbonic acid of the limestone, but by the black-lead mixed with the crucible; black-lead being a very highly carburetted iron.

These ideas were pursued by Mushet; who went through a course of trials on the fusion of pure malleable iron with charcoal alone in various proportions. As Mushet's experiments, have in my opinion, *settled* the theory of the formation of Steel, I shall give them at length.

On the different Proportions of Carbon which constitute the various Qualities of Crude Iron and Steel. By DAVID MUSHET, *Esq. of the Calder Iron Works.*

It is of considerable importance to the manufacturer to ascertain the absolute portion of charcoal which in his process becomes united with the metal to form cast iron. Having once admitted the fact, that it is in the ratio of the carbon presented to the metallic particles that he obtains a determinate quality of crude iron, experiment will enable him to deduce, that in manufacturing the richest natures of iron his produce from the ore will be more, by the extra quantity of carbon necessary to constitute this quality, than when the inferior numbers of iron are produ-

ced. In all cases, therefore, in making cast iron, considerable quantities of the coal become united with the iron, forming, by weight, a portion comparatively great.

From the usual processes hitherto employed in manufacturing blistered steel, the positive quantity of carbon which became united with the iron never became an object worthy of the attention of the manufacturer. It was sufficient to him that his bars possessed blisters sufficiently large and prominent to assure him that his steel was sufficiently converted. The unerring test of practice through a long series of operations confirmed the correctness of this deduction; and it must have appeared a matter of little importance to the formation of steel, that its direct operation of principle should be developed, or the laws which regulate its affinity in cementation.

No additional fact was necessary to the production of cast steel. The simple fusion of bar steel, regulated by such circumstances as practice, and the various uses to which this steel is applied, was all that was necessary to be known; the affinity of iron for carbon, and the various proportions in which it exists with the metal, forming the different qualities of steel, here met with no elucidation.

On the contrary, we still find that the union of iron and charcoal to form steel, is a matter of doubtful opinion among manufacturers, and the weight gained by its cementation generally denied.

It is only lately that a process has been brought into use for making cast steel, which has for its basis or principle the direct proportions of carbon necessary to form steel, illustrative at the same time of that beautiful phænomenon of affinity betwixt iron and carbon, which constitutes the endless varieties of this metal.

To investigate this subject with accuracy, it appeared to me that a series of experiments, made by the fusion of bar

iron with well prepared charcoal of wood in vessels completely air-tight, would be productive of the greatest nicety of result. With this view, the proportions of iron and charcoal recorded in the following experiments were each of them introduced into crucibles of Stourbridge clay while the clay was yet moist. The top was accurately closed upon the contents, and the crucibles set aside to dry for eight or ten days. Previous to the introduction into the melting furnace they were baked in a common annealing fire to bring them to an ordinary red heat: from this furnace, while hot, they were successively placed in the assay-furnace for reduction.

The following are the details of these experiments:

		Grains.
Exp. I. Pieces of Swedish iron - -		1173
Charcoal $\frac{1}{2}$, or -	grs. 581$\frac{1}{2}$	
The mixture was exposed to a moderate degree of heat for 70 minutes, when the crucible was withdrawn. When cold it was carefully examined, and found free from cracks.		
Charcoal untaken up, of a deep black colour,	310$\frac{1}{2}$	
Charcoal disappeared in the fusion -	271	

equal to 48 per cent. of the original quantity.

The button obtained was supercarbonated crude iron, and weighed. 1233

Gained in weight, by the combination of carbon, 60

equal to $\frac{1}{19}$th part fully of the first weight of iron.

The fracture of this button was exactly that of No. I. pig iron, towards the upper surface largely granulated; and below a substratum of small grained metal resembling No. III. pig iron.

	Grains.
Total weight of the mixtures -	1754$\frac{1}{2}$

Charcoal remaining	$310\frac{1}{2}$ grains.	
Iron obtained -	1233 grains.	1543
	Total loss in fusion	211

The quantity of charcoal which disappeared in this operation was equl to $\frac{1}{4\frac{3}{10}}$ th part the weight of the iron.

		Grains.
Exp. II. Swedish bar iron - -		1093
Charcoal $\frac{1}{4}$, or - -	grs. $273\frac{1}{4}$	

The fusion of this mixture was effected in fifty minutes. When cold, the crucible was found entire, and containing of charcoal not taken up $90\frac{1}{4}$

Lost in the fusion 183

equal to 67 per cent. of the original weight of charcoal. A fine button of supercarbonated crude iron was found, which weighed - 1143

Gained in weight by combination of charcoal 50

equal nearly to $\frac{1}{22}$d part the weight of the iron employed. The fracture of this button was inferior in point of lustre and prominency of crystal. It was, however, similar to the usual run of the No. I. iron of the manufacturer.

The quantity of charcoal which disappeared in this experiment was equal to $\frac{1}{6}$th part the weight of the iron.

		Grs.
The aggregate of the mixture weighed		$1366\frac{1}{4}$
Charcoal remaining	$90\frac{1}{4}$ grains.	
Iron obtained -	1143 grains.	$1233\frac{1}{4}$
	Lost in weight upon the whole	133

Exp. III. Swedish iron in pieces - -		1143
Charcoal $\frac{1}{6}$th, or -	grs. 190	

This mixture was fused in thirty minutes, and was allowed to cool to a low red heat

before it was removed from the furnace. Grains.
When cold, the crucible was found without cracks, and the charcoal not taken up weighed 55

Charcoal disappeared, equal to 71 per cent. 135
The metallic button now obtained was superbly carbonated so as to resemble a mass of carburet of iron. It weighed - - 1193
Original weight of the iron - 1143

Gained by combination of charcoal 50
equal nearly to $\frac{1}{23}$d part the weight of the iron. All the surface presented by this button was uniformly covered with a rich and lustrous coating of carburet, indicating a superior quality of crude iron. The quantity of charcoal which disappeared on this fusion was equal to $\frac{1}{8\frac{1}{2}}$d part the weight of the iron employed.

The aggregate of mixture here weighed - 1333
Charcoal not taken up 55 grains.
Iron obtained - 1193 grains. 1248

Total loss in the melting 85

It is worthy of remark, that the loss of charcoal in these experiments, together with the general loss in fusion, diminish, in a series proportionate to the quantity of charcoal introduced, bearing no perceptible relation to the quantity of iron. The weight gained by the metallic buttons respectively, indicate nearly the same degree of saturation of the carbonic principle, whatever difference of appearance existed as to external appearance in No. III. It therefore appeared a matter of some curiosity, worthy of investigation, what became of the extra loss of carbon in No. I. and II. beyond that sustained in No. I. when the richest iron was produced.

Charcoal disappeared	No. I.	II.	III.	
Equal to - -	$\frac{1}{4\frac{3}{10}}$	$\frac{1}{6}$	$\frac{1}{8\frac{1}{2}}$	
Gained by iron - -	$\frac{1}{19}$	$\frac{1}{22}$	$\frac{1}{23}$	Average $\frac{1}{21\frac{1}{3}}$d part.
General loss in fusion	211	133	85	Grains.

Exp. IV. Swedish iron - - - 1060

Charcoal $\frac{1}{10}$th, or 106 grains.

From this mixture a very perfect fusion was obtained, in which all the charcoal disappeared except about grain$\frac{1}{2}$ composed of small granules possessing a rich deep black colour. The metallic button weighed 1093

Gained by the combination of charcoal 33

equal to $\frac{1}{33}$d part the weight of the iron employed. In addition to the weight of the button, the sides and top of the crucible contained a considerable number of minute spheres of iron possessing prismatic colours. The surface of the present product was crystalized in radii. The fracture was that of highly blown crude iron of a pale silvery white colour, marked with an imperfect crystallization. The quantity of charcoal which disappeared in this operation was equal to $\frac{1}{10}$th part the quantity of iron at first introduced.

	Grains.
The aggregate weight was - - -	1166
Charcoal remaining $\frac{1}{2}$ grain, and iron obtained 1060	$1060\frac{1}{2}$
Total loss in this fusion	$105\frac{1}{2}$

Exp. V. Swedish iron - - - - 1000

Charcoal $\frac{1}{15}$th, or - - - 66

This fusion was found complete after half an hour's exposure. The charcoal had totally disappeared. The metallic button was regularly crystallized, and weighed 1000 grains, being exactly the same weight introduced. Be-

sides the button, some thousands of metallic globules entirely covered the sides and concave top of the crucible. It was found impracticable to collect them all. By estimation they appeared to be from 15 to 20 grains. The fracture of this button was whitish blue, clear, and possessed a lustre similar to the fracture of zinc. An approximation to grain was visible, and, from minute comparison, a very early stage of steel was indicated.

	Grains.
The aggregate of the mixture weighed -	1066
Button of iron 1000, globules taken at 20, -	1020
Total loss in the fusion	46

Exp. VI. Swedish iron - - 1035

Charcoal $\frac{1}{20}$th, or - $51\frac{1}{2}$ grains.

The mixture yielded, by fusion, a metallic button partially crystallized, weighing - - 1032

Lost in fusion, equal to 312th part, 3

The charcoal had entirely disappeared. The fracture of this button displayed a very regular grain, similar to that of steel. In subjecting it to forging and other tests, it proved to be steel of a soft quality.

	Grains.
Original weight of mixture -	$1086\frac{1}{2}$
Iron obtained - - -	1032
Total loss in fusion	$54\frac{1}{2}$

Exp. VII. Swedish iron - - - 1055

Charcoal $\frac{1}{30}$th part, or 35 grains.

A very perfect fusion was obtained from this exposure. The metallic button was found beneath a covering of glass possessed of a white streaky surface, the mass of which was of the transparency and colour of a smoky topaz: it was found to weigh - 1052

Lost in fusion, equal to $\frac{1}{351}$th part the original iron 3

In this experiment, also, the charcoal had completely disappeared. The present product was minutely examined, but gave no indications of steel. After being deeply cut with a chisel, it was broken with very great difficulty across the anvil. It was then forged, and plunged hot into water; but did not harden. It generally resembled those qualities of iron obtained by fusion with earths and glasses. This experiment was repeated four times, and always attended with a similar result; so that it seemed deducible from it, that $\frac{1}{30}$th part of carbon in addition to any quantity of iron was insufficient to form steel; and, referring to the result of No. VI. it appeared that even $\frac{1}{20}$th part formed a steel much too soft for the general purposes of manufacture. This conclusion, however, being at variance with facts I had already established upon the formation of cast steel in common crucibles, was here inadmissible. It was therefore necessary to seek for an explanation of the phænomenon of the charcoal disappearing in close vessels, formerly alluded to, before any certain knowledge of the exact quantities of charcoal could be ascertained, which were necessary to form either cast iron or steel in vessels made impervious to the air. I uniformly remarked in the present experiments, that when the quantity of charcoal introduced was from $\frac{1}{30}$th to $\frac{1}{200}$th the weight of the iron, a portion of glass was constantly formed upon the surface of the metallic button. The quantity generally increased as the proportion of charcoal decreased; so that, in some experiments, 300, 350, and 400 grains of amber-colour glass was obtained. The The colour was blueish black, smooth in the centre but a little oxdated towards the edges. Its fracture presented close dark grey crude iron. The crystals much closer and more minute than in those experiments where richly carbonated crude iron was obtained. Appreciating its

upper surface of this glass was frequently of a pure pearly white colour. In one experiment, where $\frac{1}{70}$th of charcoal was used, I obtained a large quantity of glass cellular throughout. Each cell was surmounted upon the top with concentric circles of pearly lines, forming a curious and pleasing effect.

Having fully satisfied myself that operations performed in close vessels thus prepared were subject to uncertainty, arising as well from the formation of glass as from some unknown affinity exerted upon the charcoal; and having performed several experiments with well filled open crucibles, with charcoal alone, wherein I found little comparative loss, I performed a very accurate series of experiments, viz.

Having selected a parcel of well-prepared Stourbridge clay crucibles, with covers exactly fitting, I proceeded to make the following experiments upon the quantity of charcoal which forms crude iron and steel; first premising that both crucible and cover were brought to a bright red heat before the substances acted upon were introduced. This was done with the greatest possible caution, to avoid volatilizing any part of the charcoal, and rendering the result inaccurate. From the approximation of these results in repeating most of these experiments, I found that no material difference had occurred.

		Grains.
Exp. I. Swedish bar iron - -		885
Charcoal $_{2}$, or -	grs. 442	
This mixture was exposed for half an hour, and a perfect button of supercarbonated crude iron was obtained. Along with the metal was found of intensely black charcoal not taken up -	290	
Charcoal disappeared, equal to 34·4 per cent.	152	
The metallic button now obtained was found to weigh		928

Gained in weight by the combination, equal to $\frac{1}{20\frac{1}{2}}$ grs.
part of the original weight of the iron - 43
Charcoal disappeared - - 152

Total loss in charcoal 109

Collective weight of the iron and charcoal originally
introduced - - - grs. 1327
Iron obtained in the fusion grs. 928
Charcoal not taken up - 290
1218

Total loss in this experiment 109

Exp. II. Swedish bar iron - - 925
Charcoal one fourth part, or - grs. $231\frac{1}{4}$
This mixture, after a similar exposure, was
completely fused. When cold, the crucible
was found to contain of very fine charcoal $125\frac{1}{4}$

Charcoal disappeared in the fusion, equal to
45 per cent. - - - - 106
The metallic button was richly carbonated, and
weighed - - - - - 972
Gained in weight by the union of charcoal,
equal to $\frac{1}{19\frac{9}{10}}$ th part of the original weight
of the iron, - - - - 47
Charcoal disappeared - - - 106

Lost in fusion 59

Collective weight of iron and charcoal originally
introduced - - grs. $1156\frac{1}{4}$
Iron obtained in the fusion grs. 972
Charcoal not taken up - $125\frac{1}{4}$
1097

Total loss in this experiment 59

grs.

Exp. III. Swedish bar iron - - - 915

Charcoal ⅙th, or - grs. 152

This mixture was subjected to a similar heat, and a perfect fusion effected. There was found of charcoal not taken up - - 65

Charcoal disappeared, equal to 57 per cent. 87

The metallic button resembled the produce of No. I. and II. and weighed - - - 960

Gained by the fusion, equal to $\frac{1}{20\frac{3}{10}}$th part the first weight of the iron - - - - - 45

Charcoal disappeared - - - 87

Lost in the fusion 42

Collective weight of the iron and charcoal used 1067

Iron obtained - - grs. 960

Charcoal remaining - - 65

1025

Total loss in this experiment 42

Exp. IV. Swedish bar iron - - 977

Charcoal one eighth, or - grs. 122

This mixture entered into fusion in nearly the same time as the former. There was found on the surface of the metal a portion of very beautiful carbon, which weighed 40

Lost of charcoal in fusion, equal to 67 and 2 tenths per cent. - - - 82

The metallic button obtained in this experiment was superbly carbonated, and apparently formed an entire mass of carburet. It weighed - - - - - - 1020

Gained in weight by the union of carbon, equal

			grs.
to 22 and four tenth part the first weight of the iron - - - - - -			43
Charcoal disappeared - - -			82
Lost in the fusion			39
Original weight of the mixture -		grs. 1099	
Iron obtained - -	grs. 1020		
Charcoal remaining - -	40		
		1060	
Total loss in this experiment			39
Exp. V. Swedish bar iron - - -			1125
Charcoal one ninth, or -		grs. 122	
From this fusion was obtained a supercarbonated button of crude iron, upon the surface of which was found of fine charcoal		25	
Lost of charcoal, equal to 80 per cent.		97	
Compared with the former results, the metal now obtained was inferior in point of carbonation. Its surface was smooth, and of a dull lead colour; entirely free from the usual shining specks of carburet which very rich crude iron contains upon its surface. It weighed -			1168
Gained in fusion, equal to one 26th part the weight of iron employed - - -			43
Charcoal disappeared - - - -			97
Loss in the fusion			54
Collective weight of the mixture		grs. 1247	
Weight of metallic button	grs. 1168		
Charcoal not taken up -	25		
		1193	
Total loss in this experiment			54

		grs.
Exp. VI. Swedish iron - - -		880
Charcoal one twelfth or -	grs. 73	
This was sufficiently heated to produce fusion. When cold, there was found upon the surface of the metal a portion of very black charcoal weighing - - - -	12	
Lost in the fusion, equal to 83 and a half per cent.	61	
The metallic button possessed a uniformly smooth surface, partially covered with carburet, and weighed		920
Gained by the combination of charcoal, equal to one twenty second part - - - -		40

Collective weight of the mixture originally introduced - - -	grs. 953	
Charcoal not taken up - grs. 12		
Iron obtained - - 920		
	932	
Lost in the fusion		21
Charcoal disappeared -	grs. 61	
Iron gained in weight -	40	
Total loss in this experiment		21

From the results of these experiments it becomes obvious that bar iron may be converted into the finest qualities of crude iron by the addition of any portion of charcoal from one half to one twelfth part its weight: that in passing from the malleable to the carbonated crude state, it uniformly gains in weight by a combination of carbonaceous matter equal to $\frac{1}{20\frac{1}{2}}$, $\frac{1}{19\frac{9}{10}}$th, $\frac{1}{20\frac{3}{10}}$th, $\frac{1}{22\frac{4}{10}}$th, $\frac{1}{26}$th, $\frac{1}{22}$d: average $\frac{1}{21\frac{8}{10}}$th part its own weight.

It is here again worthy of remark, that in all these experiments with open vessels, a portion of charcoal disappeared always in proportion to the quantity introduced, and not analogous to the quantity of iron.

Disappeared of Charcoal		Iron gained.
When one half was used, 34·4 per cent.	-	$\frac{1}{20\frac{1}{2}}$th, part.
When one fourth was used, 45 per cent.	-	$\frac{1}{19\frac{1}{10}}$th part.
When one sixth was used, 57 per cent.	-	$\frac{1}{20\frac{3}{10}}$th part.
When one eighth was used, 67·2 per cent.	-	$\frac{1}{22\frac{4}{10}}$th part.
When one ninth was used, 80 per cent.	-	$\frac{1}{26}$th part.
When one twelfth was used, 83·5 per cent.		$\frac{1}{22}$d part.

Upon the whole, if the results of these six experiments, performed in open vessels, are compared with the three first detailed in last communication, where a similar quality of crude iron was obtained in vessels perfectly close, no material difference will be found. They mutually support each other, as to the quantity of carbon necessary to form crude iron, while they still leave in doubt the cause of the disappearance of the charcoal in close vessels. In the case of open vessels, it is highly probable that a considerable portion of the charcoal is destroyed before the heat of the furnace is sufficiently strong to lute the cover of the crucible.

This still, however, leaves unexplained, why, in experiment I. a loss of 152 grains of charcoal is sustained; while in No. VI. the original quantity introduced did not amount to half that quantity, yet 12 grains of the latter was found entire resting upon the surface of the reduced metal. The thickness and capacity of the crucible in both cases, and, indeed, all these experiments, were nearly alike.

The fact of malleable iron being convertible into the most carbonated state of crude iron, either in close or open vessels, where a portion of the carbonaceous matter was found reposing upon the surface of the newly-changed metal, creates some doubts as to the existence of oxygen in

crude iron. If it be admitted that bar iron is destitute of oxygen, which it is highly probable is the case; if a portion of this iron be introduced and fused along with a portion of carbonaceous matter in a vessel impervious to air, which vessel is found, when cold, to be more than half filled with charcoal, protecting a metallic button of crude iron below; it is with the greatest difficulty we can admit of the presence of oxygen in the metallic mass. It may be urged, that charcoal, considered as an oxyd of carbon, might impart a partion of oxygen to the metal. This must suppose, however, a continual action and reaction of affinity, wherein it is presumable the carbon would finally prevail, and carry off the oxygen. I conceive it more just to suppose, that what quantity of oxygen was contained in the charcoal, would be discharged by the latter deoxydating itself analogous to its superior affinity, rather than combining with the iron.

It is a fact well known amongst manufacturers, that cast iron of a silvery white fracture may be saturated to excess with carbonaceous matter simply by cementing it in contact with charcoal. In this process it acquires a soft grey fracture, easily reducible by the file. If this cast iron originally contained oxygen, a long cementation in contact with charcoal, most likely, would deprive it of this; yet we find it still possessed of all the properties of cast iron. From this we should be apt to conclude that oxygen at least is not necessary to the production of crude iron.

Again, in the process of cementation, bar iron is first changed, by a comparatively small dose of carbon, into steel. If this steel, by accident or intention, be continued somewhat longer in the furnace under an increased temperature, an excess of affinity is established betwixt the metal and the charcoal without the presence of a third principle: the steel becomes gradually more and more carbonated: it changes its fracture of granulation, if I may be

allowed the term, from that peculiar to blistered steel, through all those breaks peculiar to the respective qualities of crude iron; and may at last pass into the state of a carburet of iron totally different in its properties and appearance from either steel or crude iron. This process may be carried on to the utter exclusion of atmospheric air; and here, if the process is stopped in its proper stages, will be found all the various qualities of crude iron formed without perfect fusion, where we cannot conceive oxygen to have existed.

I am aware of adducing circumstances from these experiments, at variance with the present received opinions upon the constituent parts of cast iron, and also in opposition to principles which I have formerly laid down. I wish not the present hints to be considered as assertions. As irreconcileable in some degree with former opinions, I wish they may lead to an ample investigation of the subject. The distinction hitherto made betwixt crude iron and steel, particularly by the French chemists, has been, that crude iron was the metal imperfectly reduced, but that the latter was iron perfectly reduced, combined with a small portion of carbon. The fact, however, of malleable iron passing into the state of fine crude iron without the contact of an oxygenous body, puts it upon a similar footing with steel, only altered by a greater comparative quantity of carbon. This reduces us to the necessity of drawing one of the two following conclusions: that steel is, equally as crude iron, a combination of iron, carbon, and oxygen; or, that crude iron differs from steel only in the proportion of the carbon with which it is saturated.

Exp. VII. Swedish bar iron - grs. 1174

Charcoal $\frac{1}{15}$th part, or 78 grs.

A fusion was obtained from this mixture, after which there remained only a small portion of char-

grs.

coal, too minute for weighing.

The metallic button weighed - - 1213

Gained in weight by the combination of charcoal 39
equal to $\frac{1}{30}$th part the weight of the iron.

Weight of the iron 1174, and charcoal 78, = 1252
Weight of the button - - - - 1213

Total loss of weight in the fusion 39
equal to that gained by the iron. Upon minute inspection, no part of the surface of this button was carbonated. The colour was blueish black, smooth in the centre but a little oxidated towards the edges. Its fracture presented close dark grey crude iron. The crystals much closer and more minute than in those experiments where richly carbonated crude iron was obtained. Appreciating its real quality by comparison with crude iron manufactured for sale, it occupied that rank generally known by the names of No. II. grey melting pig iron.

Exp. VIII. Swedish bar iron - - grs. 922

Charcoal $\frac{1}{20}$th part, or 46 grs.

From the exposure of this mixture there resulted a very perfect metallic button whose upper surface presented a partial degree of radiated crystallization. It was found to weigh - - - 950

Gained in weight by the combination of carbon 28
equal to $\frac{1}{33}$d part the original weight of the iron. The fracture of this button was smooth, silvery white, occasionally studded with carbonaceous specks in the form of small grains, an exact resemblance to mottled pig iron. In this experiment there remained not the most distant trace of carbonaceous matter. A small portion of amber-coloured glass was formed round the edges of the metal.

	Grains.
Weight of the iron 922, charcoal 46, = -	968
Metal resulting - - -	950
Total loss of weight	18

Exp. IX. Swedish bar iron - - 1330

Charcoal $\frac{1}{25}$th part, or 53 grs.

From this mixture a perfect fusion and metallic button was obtained, which weighed - 1351

Gained in weight by the combination of carbon 21 equal to $\frac{1}{63}$d part the weight of the iron. In this experiment also the charcoal had completely disappeared. The upper surface of the button was smooth, the under surface considerably pitted. The concaves chequered with a rude crystallization peculiar to cast iron. The fracture of this metallic mass was bright silvery white, destitute of grain, and exhibiting a very perfect streaky crystallization slightly radiated. Its resemblance was strikingly similar to that of highly blown cast iron prepared in the finery for the purposes of bar iron making; an operation commonly in use for the purpose of decarbonating the iron, that it may, in the subsequent process, sooner pass into the state of malleability. The weight of iron and charcoal in the experiment amounted to grs. 1383

Iron obtained - -	1351
Total loss in the fusion	32

Exp. X. Swedish iron - - 1348

Charcoal $\frac{1}{30}$th, or 45 grs.

From this proportion of mixture in half an hour a perfectly fused button of metal was obtained, which was found to weigh - - 1359

Gained in weight by the combination of carbon 11

equal to $\frac{1}{122}$d part the original weight of the iron. The upper surface of this button was smooth without configuration. Below the surface was uneven, and covered with minute but perfect crystallization. Its fracture was blueish silvery white, composed of flat dazzling crystals, proceeding in lines from a centre to the edges of the button. Here it was most obvious, that from the smallness of the proportion of carbon presented to the iron, the resulting product was found assuming the earliest stage of granulation approaching to the steely state. The brilliant concretions observable in the surface of the button were too indistinct and flat for steel capable of withstanding the hammer.

	Grains.
The joint weight of the iron and charcoal amounted to	1393
Iron obtained - - - -	1359
Total loss of weight in the fusion	34

Exp. XI. Swedish iron - - 1502

Charcoal $\frac{1}{40}$th, or 37 grs.

The metallic button obtained by the fusion of this mixture weighed - - -	1505
Gained in weight by the union of carbon	3

equal to $\frac{1}{500}$th part the first weight of iron. The upper surface of this button was smooth, with a faint impression of a chequered crystallization. The under surface possessed some large pits similarly though more perfectly crystallized.

The fracture possessed one shade of blue beyond that of No. X. A regular granulated surface composed of flat oblong crystals was observable, still too indistinct and too much on edge for workable steel. The weight of charcoal and iron in this experiment amounted to grs. 1539

Metal obtained - -	1505
Total loss of weight in the fusion	34

Exp. XII. Swedish iron - - grs. 1537

Charcoal $\frac{1}{50}$th, or 31 grs.

From the exposure of this mixture, a metallic button was obtained, which weighed - 1533

Lost in fusion, equal to $\frac{1}{384}$th part 4

The surfaces of this button were uniformly smooth. The fracture was dense, and displayed a grain peculiar to highly saturated blistered steel. When put under the hammer, with a low red heat, it stood a few blows, but afterwards parted. Weight of mixture employed in the experiment grs. 1568

Steel obtained - - 1533

Total loss of weight 35

Exp. XIII. Swedish iron - - 1362

Charcoal $\frac{1}{90}$th, or 15 grs.

A very fine fusion was produced from the exposure of this mixture. The metallic button was found to weigh 1319

Lost in fusion, equal to $\frac{1}{31\frac{6}{10}}$th part, 43

This button presented a wavy crystallized surface. The under surface was rough, and contained one large pit accurately crystallized. The fracture was regularly granulated, small, but distinct, of a light blueish colour. The crystals, though distinct, were not so prominent as those of easy drawing cast steel. It, however, hammered with the usual degree of caution necessary to the working of cast steel. The bar of steel formed from the button possessed all those properties requisite for file making, and other purposes requiring a quality highly charged with carbonaceous matter. Grs.

Weight of the mixture - - 1377

Steel obtained - - - 1319

		Grs.
Loss of weight in this experiment		58
Exp. XIV. Swedish iron	- -	1372
Charcoal $\frac{1}{100}$th, or 14 grs.		
The button obtained weighed	- -	1312
Lost in the fusion		60

equal to $\frac{1}{22\frac{8}{10}}$th part the original weight of the iron. The surface of this button was smooth, without crystallization. The under surface rough, and possessed of one large pit in the centre, faintly marked with the usual crystalline appearance. The fracture presented regular light blue grains distinct, and more prominent than No. XIII. One-half of the button was drawn into a neat square bar, and proved steel of an excellent quality. One end of the bar being loose and shaled, welded tolerably well, and hardened afterwards with a low heat. In appreciating the quality of this result, it appeared to be that kind of steel suitable for penknives, razors, &c. possessed of neither the extremes of hardness nor of softnesss.

Beyond the proportion of $\frac{1}{100}$th part of charcoal to iron, I continued the experiment till the proportion was reduced to $\frac{1}{200}$th part. It would appear tedious to detail these experiments, the most interesting being already minutely described. In the same progressive manner, by diminishing the dose of carbon, the metallic result approached more and more to the softness of malleable iron, though by no means possessed of all its properties. In this series of experiments, iron presented with $\frac{1}{120}$th part its weight of charcoal was found to form very soft steel fit for making scissars, &c. which, in a good workman's hands, would have doubled, welded, and formed a very perfect point, afterwards hardening so as to display a beautiful close break of steel. By using the following precaution, it was even found capable of welding perfectly to

iron. Two flat bars of a similar shape, one of this quality of steel, and one of good malleable iron, were put under the hammer with a good welding heat. After a few light blows, the junction was completely made. The united bars were allowed to cool without further hammering till the shade of heat was bright red. The whole piece was then drawn out in a solid compact form, whose fracture, when cold, presented a complete junction of the iron and steel, exhibiting at the same time their respective grains.

When iron is presented in fusion to $\frac{1}{140}$th or $\frac{1}{150}$th part of its weight of charcoal, the resulting product occupies a kind of middle state betwixt malleable iron and steel. It then welds with facility, and, provided the precaution formerly mentioned is attended to, may be joined either to iron or steel, at a very high welding heat. Thus combined with carbon, it is still susceptible of hardening a little, but without any great alteration in the fracture. It possesses an uncommon degree of strength and tenacity, capable of an exquisite degree of polish, arising from its complete solidity and the purity of fracture conveyed to it by fusion.

When the dose of carbon is further diminished, and in the ratio of this diminution, the same steel or iron becomes more and more red short, and less capable of cohesion under a welding heat, so that, when the proportion is reduced to $\frac{1}{200}$th part the weight of the iron, the quality resulting is nearly analogous to the fusion of iron *per se*, or that obtained by the fusion of iron and earths.

It will appear evident from the result of these and former experiments, that crude iron and steel only differ from each other in the proportions of the carbon they contain. In thedetails now before us, charcoal alone is used in addition to the malleable iron as pure as is ever made, to effect every principal stage or modification of the metal. Hence we conclude, that

Iron semi-steelified is made with, charcoal,	$\frac{1}{150}$th part.
Soft cast steel, capable of welding, with,	$\frac{1}{120}$th
Cast steel, for common purposes, with,	$\frac{1}{100}$th
Cast steel requiring more hardness, with, of charcoal, - - -	$\frac{1}{90}$th part.
Steel capable of standing a few blows, but quite unfit for drawing, - -	$\frac{1}{50}$th
First approach to a steely granulated fracture, is from - - -	$\frac{1}{30}$th to $\frac{1}{40}$th
White cast iron - -	$\frac{1}{25}$th
Mottled cast iron - -	$\frac{1}{20}$th
Carbonated cast iron - -	$\frac{1}{15}$th
And supercarbonated crude iron -	$\frac{1}{12}$th, or when any greater quantity is used.

Although this is the quantity of charcoal necessary to form these various qualities of metal by this mode of synthesis, yet we are by no means authorized to conclude that this is the proportion of real carbonaceous matter taken up by the iron, seeing that in experiments No. I. to No. VI. inclusive, the weight gained by the iron was upon the average equal only to $\frac{1}{21\frac{8}{10}}$th, part; whereas the charcoal which disappeared in the different fusions amounted to 61. 1 per cent. of the original quantity introduced along with the iron.

In the succeeding experiments the following differences are remarkable :

No. VII.	Charcoal used.	$\frac{1}{15}$th	-	Iron gained	$\frac{1}{36}$th part.
No. VIII.	-	$\frac{1}{20}$th	-	-	$\frac{1}{33}$d
No. IX.	-	$\frac{1}{25}$th	-	-	$\frac{1}{63}$d
No. X.	-	$\frac{1}{30}$th	-	-	$\frac{1}{122\frac{1}{2}}$
No. XI.	-	$\frac{1}{40}$th	-	-	$\frac{1}{500}$th
No. XII.	-	$\frac{1}{50}$th	-	Iron lost	$\frac{1}{384}$th
No. XIII.	-	$\frac{1}{90}$th	-	-	$\frac{1}{36\frac{6}{10}}$th
No. XIV.	-	$\frac{1}{100}$th	-	-	$\frac{1}{22\frac{8}{10}}$th

From this we see that when a proportion of charcoal equal to one fortieth part, and above, the weight of the iron is used, the latter always gains in weight; but when a more sparing proportion is introduced, room is left for the exertion of another affinity upon the metal, and it consequently and invariably loses in weight proportioned to the diminution of the carbon. I have here further to remark upon the foregoing experiment, and upon the nature of experiments by synthesis performed in this way in general, that the results as to quality will differ materially when different portions of matter are used. So that an operator repeating the above experiments either in crucibles smaller or larger, or with a greater or less weight of mixture, would not obtain the same results.

The formation of cast steel in the large way, founded upon the results of the foregoing experiments, affords an incontestable proof of this. In fusions of 18, 22, and 25 lbs. of iron each, we are obliged to increase the dose of carbon considerably beyond that requisite in small experiments. To form steel equal to that obtained in experiment XIII. wherein one ninetieth of charcoal was used, one fifty-fifth part is requisite to be introduced. For steel similar to that in experiment XIV. one sixty-fifth and one seventieth part are used. For softer steel one ninetieth, whereas in the small experiment 1 one hundred twentieth part was sufficient. If in the manufacturing a small extra quantity of carbon is requisite, this is saved by the comparatively small loss sustained in the transmutation of the iron into steel.

Many instances have occurred in the first fusion from a cast steel pot in the large way, where 25lbs. of iron, and its requisite proportion of carbon, not exceeding one seventieth, have afforded an ingot of cast steel weighing 24lbs. 12, 13, 14, and 15 ounces, being a loss equal to no more than 1 one hundred tenth, 1 two hundredth, 1

three hundredth, 1 four hundredth part the weight of the iron, whereas in experiments No. XIII. and XIV. the loss of metal amounted to one 31 six tenth, and one 22 eight tenth part the weight of the iron.

I shall conclude this paper with a few remarks upon the state in which carbon exists in steel and in crude iron.

When malleable iron is fused with 1 one hundredth thirtieth or 1 one hundred fortieth part of its weight of carbon, the resulting product is considerably steelified. The fracture is lighter in the colour than it formerly was in the state of iron. When fused with an 80th to 1 one hundredth, steel of an ordinary quality is produced, the fracture of the metal still becoming whiter. When the dose of carbon is increased beyond this, the steel becomes so hard and dense as to be unfit for hammering. The fracture now will be found approaching to the colour of silver, and losing its granulated appearance, assuming, however, a crystallized form. In this state the metal will be found to resist the hammer and file, and to be unfit for any purpose. Increase, however, the quantity of carbon to one twelfth or one fifteenth, the resulting product is no longer destitute of grain, nor possessed of the same degree of hardness. The fracture will be found grey, and the surface easily reduced by the file. A further increase of the carbon is accompanied by an increase of these properties. At 1-8th or 1-6th, the filings of the metal, when thrown into water, leave a carbonaceous pellicle covering the whole surface, and of a considerable thickness.

Thus we find that carbon hardens iron till it arrives at the highest pitch of density, which is indicated by the metal losing grain, and assuming a crystallized silvery fracture. At this point or maximum we may conceive that the respective proportions of mixtures are so nearly balanced that the affinity exerted by the iron is just sufficient to deoxydate the charcoal, and that hitherto nothing

but pure carbon similar to the diamond has combined with the iron. If, however, the equilibrium is destroyed by a larger portion of charcoal, then we find the affinity too weak to deoxidate the whole, and part of it unites in the state of an oxide of carbon; at first constituting a mottled fracture, and afterwards, as the dose is increased, all those deepening blueish grey shades peculiar to soft cast iron. Hence carbon or its oxide again softens iron. It never, however, restores the properties of forging or of hammering. One invariable law, however, is maintained, that the fusibility of iron under every circumstance and modification is in the ratio of the quantity of carbon united."

In consequence of these experiments, Mr. Mushet took out a patent for the manufacture of cast steel, which is couched as follows.

Account of Mr. MUSHET'S *new Method of making Steel of various Qualities.*

"For this invention Mr. Mushet* has obtained his Majesty's royal letters patent; and, certainly, few discoveries of so much importance to this country have been made for a number of years past. The manufacture of cast steel, which has hitherto been tedious and expensive, is now reduced to a process of a few hours; and the quality of the article at the same time so much improved, as to be applicable to many purposes to which steel of the common manufacture cannot be applied. We shall not, however, dwell on the utility of the invention, but lay before our readers an account of it, extracted from Mr. Mushet's specification, which will speak more to an intelligent mind than would a volume of eulogium.

* Mushet's experiments have certainly thrown great light on the theory of steel; but I do not know whether his patent has been extensively used, or his steel compared with Huntsman's. T. C.

" The general principles of my process or processes are the fusion of malleable iron, or of iron ore, in such manner, and by such means, as immediately to convert them into cast steel; and, likewise, in certain cases, the after cementation of this steel to give it malleability, and the property of welding, in order to fit it for such purposes as require steel possessing these properties. These principles can be acted upon for the production of the various qualities of steel in a variety of ways; but the principle of my invention, and the mode of operation, may be fully understood by the examples which I shall adduce, and which will enable any person to perform the same, and to vary and alter the mode of operation according to his intention, and the particular quality of steel he may wish to manufacture.

" Thus, cast steel may be made by taking any convenient quantity of malleable iron, according to the size of the furnace and crucible or crucibles to be employed, and introducing it into the crucible or crucibles along with a proper proportion of charcoal, charcoal dust, pit-coal, pit-coal dust, black lead, or plumbago, or of any substance containing the coally or carbonaceous principle; but, in general, charcoal, pit-coal, or pit-coal cokes, especially if prepared in the manner hereinafter described, will be found to answer best. For this process not only bar iron may be employed, but also what is commonly called scraps, or waste iron: but, when the latter is used, a little more carbonaceous matter must be added to the mixture, to revive the rust, or oxide of iron, adhering to the scraps. The mixture in the crucible or crucibles must then be put into a furnace capable of giving a sufficiently intense degree of heat to run down or fuse the mixture, which must then be poured out into bar, ingot, or other moulds, according as the manufacturer intends to produce bars or ingots, or various articles or utensils that are

or may be, made of cast steel; for the whole iron, by fusion with the charcoal or other substances or things containing carbonaceous matter, will be found to have passed into the state of cast steel. If cast into bars or ingots, and a proper quantity of charcoal, or other substances or things containing carbonaceous matter, has been employed, such bars or ingots will be found in a state ready to take the hammer, and to be drawn or rolled into other shapes, according to the intention of the manufacturer. In some cases, especially where a heavy charge is to be run down, the crucibles must be previously properly disposed in the furnace, and the mixture introduced into them afterwards.

" By the process before described, and which may be varied with circumstances by any prudent operator, cast steel may be made in a few hours, which, by the process or processes hitherto discovered, has usually required many days, and sometimes weeks; for cast steel, by the common method of manufacture, has been hitherto made from bar steel, which had previously required, for its own conversion into that state, from the state of bar-iron, or of scrap-iron, a tedious cementation with charcoal, in a furnace constructed for the purpose, and usually known among manufacturers by the name of a *converting furnace.*

" It cannot here escape observation, that this is not the only saving in point of time and expense, gained by my process or processes; for, when I meet with or procure iron-stones or iron-ores sufficiently rich, and free from foreign mixtures, I save even the time and expense necessary for the conversion of such iron-stone or iron-ore first into cast or pig-iron, and afterwards by a tedious and expensive process, accompanied with a great waste of metal, into bar-iron. For such ore or iron-stones, being previously roasted or torrified, when that process may be found necessary, which will often happen, may be substituted for the bar-iron, scrap or waste iron, as before described,

and the result will be cast-steel, if a proper quantity of charcoal, charcoal-dust, pit-coal, pitcoal-dust, plumbago or black lead, or of any substance containing carbonaceous matter, has been used.

"For the common and ordinary qualities of cast-steel, a much smaller quantity of carbonaceous matter is requisite in the mixture than perhaps could have been suspected before my invention. When charcoal from wood is employed, a seventieth to a ninetieth of the weight of the iron will generally be found sufficient. When the quantity of the carbonaceous matter or principle exceeds one seventieth, and is increased to from one sixtieth to one fortieth or more of the weight of the iron, the steel becomes so completely fusible that it may be run into moulds of any shape, and be capable afterwards of being filed and polished. Hence by casting may be constructed stoves, grates, kitchen utensils, many kinds of wheels and mill works, a great variety of small machinery, and many other articles, which could not be so made by the processes now in use, and which way of making such articles constitutes a part of my invention.

"By my process various kinds of steel, differing as much from each other in their qualities as the various kinds of pig or cast-iron differ from each other, can be formed by merely varying the proportion of carbonaceous matter. Cast-steel of the common and ordinary qualities is too volatile when in fusion to admit of being run into any shape except straight moulds of a considerable diameter; but steel of such density as to admit of being cast into any form may be produced by my process, by increasing the quantity of charcoal, or matter containing the carbonaceous principle, and then fusing the mixture as before directed. When I wish to produce qualities of steel softer than is usually manufactured by the common processes, I find it best to use a small proportion of charcoal, some-

times so little as a two hundredth part of the weight of the iron. Steel produced with any proportion of charcoal, not exceeding a hundredth, will generally be found to possess every property necessary to its being cast into those shapes which require great elasticity, strength, and solidity. It will also be found generally capable of sustaining a white heat, and of being welded like malleable iron; and, indeed, as the proportion of charcoal or other carbonaceous matter is reduced, the qualities of the steel will be found to approach nearer to those of common malleable iron.

"By further pursuing the principle of my new invention, I fuse down malleable bar or scrap-iron in a crucible or crucibles, without any visible addition of carbonaceous matter, and run it into bar, ingot, or other moulds. In this state the metal is nearly of the same quality as when put in, only altered by the combination of a small portion of carbonaceous matter, which the iron by its chemical affinity attracts from the ignited fuel, or from the ignited carbonic gas of the furnace, and which enters by the mouth or through the pores of the crucible or crucibles, probably dissolved in caloric at a very high temperature. But whether so dissolved or not, the fact is, that a portion of the carbon passes from the fire into union with the iron, and thereby converts it into an extremely soft steel.

"Besides the different modes of operation above specified, I further reduce iron-ore, bar-iron, or scrap-iron, by the addition of lime or chalk, or other carbonats, or of carburets, with clay, glass, and other fluxes, in various proportions, and form all the various qualities of steel formerly enumerated.

"If the various kinds and qualities of steel obtained by the process or processes above mentioned be introduced into the common converting or other steel furnaces, in contact with carbonaceous matter, or with earths, and heat-

ed for five days, or more or less, according to the thickness of the bars or other forms, and the quantity introduced, the bars, ingots, or other shapes, being then taken from the furnace, will be found to possess all the solidity which they formerly were possessed of as cast-steel, with that property of welding peculiar to blistered, faggot, or german steel of the usual mode of manufacture.

"By this invention I obtain steel which for solidity may be used for the purposes of cast-steel; uniting at the same time the property of welding, without destroying the solidity or quality of the metal: a circumstance of the highest importance to our manufacturers. Ingots, bars, plates, and every shape into which this steel is cast, rolled, or hammered, will be possessed of uniformity of quality, without those numerous reeds, flaws, blisters, and disjoined laminæ found in steel made by the processes in use before my invention.

"When pit-coal cokes are to be used in any of the foregoing operations, either in mixture with the ore, or with the iron, or for fuel in the furnaces, in which the crucibles containing the mixture are exposed to the action of the fire, it is of the utmost importance that the cokes be properly prepared. The process which I have found to answer best for this purpose, though common cokes will also do, is founded upon the principle, that all access of oxygen to the coals to be coked, should be prevented: this end is gained by preparing the cokes in iron vessels, in the same manner as wood is now charred for the purpose of being employed in the manufacture of gun-powder. The bitumen, or coal-tar as it is commonly called, which is volatilized from the coals to be coked, by the heat applied to the exterior of the iron vessel or other chamber containing the said coals is thus saved, instead of being burnt or dissipated in the atmosphere, as is the case in the common process of coking, in which the coals are

exposed to combustion in open heaps, and which also partially, though in a less degree, takes place in the process commonly known by the name of Lord Dundonald's process for preparing coal tar."

Notwithstanding Mushet's experiments fully support his theory, that steel, is pure iron united to pure carbon, and that the various kinds of steel, depend the various proportions of the carbon united to the iron, yet I am persuaded that neither in the making of cemented steel, or of cast steel, or of case hardening, do the manufacturers confine themselves to the charcoal of wood. I have before observed, that the carbon united to animal charcoal, is more easily disengaged than that which is contained in vegetable charcoal, so that for case hardening, the charcoal of hoofs, horns, bones, clippings of leather, &c. is constantly and almost exclusively preferred. We sadly want a set of experiments, shewing the effect of treating iron in a crucible with equal weights of animal and vegetable charcoal—iron enveloped with Prussian blue, and exposed to a continued heat in a close crucible of common crucible clay: for the Prussic acid is always contained in animal charcoal.—Iron so treated with ammonia or volatile alkali, and its carbonats—and another series of experiments in addition to those of Mushet, on the different results in black lead crucibles and common crucibles. Such experiments would throw new light on the theory of the combination of steel and charcoal, and of course on the practice of making steel.

Until these are made, I think I may venture for various reasons to state it as probable, that in the making of blistered and german steel, the bars are imbedded by some manufacturers in a mixture of well burnt charcoal of wood, with about one sixth of animal charcoal made from hoofs, horns, leather cuttings, &c. also, that in making of cast steel, out of the clippings of blistered steel, german steel, old files, &c. these articles are fused with limestone and bot-

tle glass, either in a black lead crucible, or in a common crucible with a small proportion of lamp-black, or the soot of train oil.

In making cast steel, I understand there is uniformly a loss: in making blistered steel, there is a gain of about half a pound in the hundred weight, which in some measure designates the quantity of carbon taken up by and united to the iron in manufacturing steel of cementation.

The charcoal in a steel furnace, is generally so much exhausted as not to answer for a second cementation; that is in point of profit.

The principal characters of steel are the following.—It becomes harder on being made red hot, and then suddenly quenched in cold water.—It takes a much higher polish than iron, with a light grey, not a blue cast or hue—If a drop of dilute nitric acid (aqua fortis mixed with three times its bulk of water) be put upon clean steel, and after a minute, washed away without being wiped off, it leaves a black spot, because although the acid will dissolve the iron, it will not dissolve the charcoal. The same acid leaves no such black spot when dropt on clean iron: only a slight grey tinge—Steel can be made much more elastic than iron: a steel sword may be bent in a vice from heel to point, and when let loose will suddenly regain its former shape; it is more sonorous than iron; its grain, or fracture, is finer than that of iron; it expands by heat more than iron; it can be beaten into thinner plates than iron; it acquires magnetic power more slowly, but retains it longer than iron; red hot steel, quenched in cold water, retains two thirds of its red-heat bulk, but iron on being so treated, contracts to its original size previous to heating; steel heats quicker, and fuses much more easily than iron; on being fused and cast, it retains the property of malleability, except at a white

heat; polished steel is sooner tinged by heat, and with higher colours than iron. This is supposed to be a partial oxydation of the surface of the metal, but as it can take place under melted lead, or hot mercury (or hot oil) not exposed to the air, this explanation is doubtful; in a calcining heat, it suffers less by burning than iron, but by repeated heating and hammering with exposure to air, the charcoal or carbon can be gradually burnt away; the same effect takes place by gradual, long repeated hammering alone; in a calcining heat, a light blue flame hovers over steel, probably owing to the gradually burning of its carbon; in a white heat exposed to the bellows, it sends off more, and brighter, and lighter-coloured sparks than iron; when covered with powdered charcoal pressed down close upon it, and exposed to a strong heat, it becomes overloaded with carbon, and acquires a slight coat resembling, and indeed consisting of black lead (Kish.) when hammered, its specific gravity is somewhat greater than iron; it leaves a residuum of black charcoal when dissolved in acids, which pure malleable iron does not. The sulphureous acid is better for the purpose than the sulphuric.

Highly carbonated cast iron differs from steel, in as much as the texture and quality of the metal is not uniform. Cast iron is scarcely malleable; it is much more brittle than steel; it is but slightly hardened or softened by heating and cooling; it is fusible in a close vessel at 130 of Wedgewood's pyrometer; the black residuum on solution in acids, is more abundant in cast iron than in steel; cast iron contains uncombined carbon, and unmettalized iron; it is more sonorous than steel.

All these properties are owing to the superior quantity of carbon or charcoal, that is united to it, partly mixed and partly in combination.

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I cannot better close this collection on iron and steel, than by Dr. Aikin's Summary.

Manufacture and properties of Steel.—Steel combines the fusibility of cast iron with the malleability of bar iron, and further possesses this very valuable property, that when heated and suddenly cooled, it becomes intensely hard, and is therefore much superior to simple iron for all kinds of cutting instruments, files and various other tools. In the present section we shall describe the different methods of preparing and tempering steel, reserving for the next section an enquiry into the chemical composition of this useful substance.

The most ancient way of making steel is probably that related by Agricola. Take some highly carburetted bar iron, cut it into small pieces and mix it with pulverized scoriæ, put the mixture into a crucible lined with charcoal, and bring it to a state of fu ion in a blast furnace. When both the iron and scoriæ are thoroughly fluid, immerse in this metallic bath, four lumps of bar iron, weighing about thirty pounds each, and let them remain in this situation during five or six hours, stirring the bath occasionally with an iron rod; by this time they will have become soft and spungy, upon which they are to be taken out and drawn down into bars by the forge hammer. As soon as this is performed, the bars still hot, are to be plunged into cold water, by which they will be rendered brittle, and are then to be broken under the hammer into short pieces. The crucible in the mean time is to be replenished with the same mixture as before; and when its contents are become quite fluid, the pieces into which the bars have been broken, are to be again immersed till they become soft: each piece being then taken out and forged separately into a slender bar, is to be cooled while yet glowing hot, in cold water, and the process is finished. The above method is we believe entirely obsolete, though with a few

modifications that are sufficiently obvious, it would in all probability be found highly advantageous.

The *native* steel of Eisenhartz in Stiria has always been in high estimation since the eighth century, and is prepared directly from the ore nearly in the same manner as common bar iron. The ore made use of, is the Spathose Ironstone, consisting of the carbonats of iron, manganese and lime, together with a mixture of clay: it is procured in vast abundance from the neighbouring hill of Arzberg, and care is taken not to use any that has not been exposed for several years to the action of the air. No flux of any kind is necessary, and the fuel, which is charcoal, does not on an average exceed in weight one fifth of the ore. When a sufficient quantity of melted matter is collected at the bottom of the furnace it is let out into a deep mould, where it remains quiet a few minutes to allow the scoriæ to rise to the surface: this being done, a little water is sprinkled over it, which hardens the scoriæ and renders them easily removable: a second but much thinner crust of scoriæ generally succeeds, which is got rid of in the same manner. A little water is now thrown on the melted metal itself, by which its surface is suddenly covered with a congealed crust about an inch thick; this is removed, and by repetitions of the same process the greater part of the mass is thus converted into these irregular plates: what remains is a mass in the state of half malleable iron. These plates are transferred to the crucible of a refinery which has been previously lined with charcoal, and are covered with scoriæ and brought to a state of fusion, carefully observing however not to direct the blast from the bellows into the crucible, lest the iron should be decarbonized. After the whole has been in quiet fusion for some time, the fire is slackened, and as soon as the metal has congealed the scoriæ still fluid are let off. The mass is then subjected to a second fusion in the re-

finery with the same precautions as at first, and is now sufficiently purified to be forged: it is accordingly extended under the hammer and cut into bars which are examined by their fracture, and separated according to their qualities, into hard steel, soft steel, and steely iron; the latter is reserved by itself and used for pointing ploughshares and other coarse work; but the others are made up into packets, observing to place the hardest steel on the inside, which are then drawn into bars at a lower heat than that required for iron, and then the process is compleat. Thus the whole art consists in purifying the cast iron, taking at the same time particular care that the carbon which it contains, is not burnt away. If the original cast iron is very highly carbonized, it sometimes happens that the steel retains too large a proportion of carbon, which is evinced in the refinery by its being more easily fusible, and requiring a longer time to become solid again than usual: this defect however is speedily remedied, by adding iron filings or scraps of bar iron, the quantity of which is regulated by the degree of fusibility to be corrected.

If the manufacturer wishes to procure iron from this ore instead of steel, the only difference required in the treatment, is to get rid of nearly the whole of the combined carbon by roasting the plates in a reverberatory furnace before they are brought to the refinery, and by avoiding to line the crucible of the refinery with pounded charcoal. The iron thus produced is of an excellent quality.

The best of the Swedish and Norwegian ores are occasionally wrought into steel of a very good quality by nearly the same process of manufacture, provided in the smelting a larger proportion than usual of charcoal has been employed, to ensure a highly carbonized metal.

The usual method of converting iron into steel is by *cementation*. For the purposes of manufacture, this is performed on large quantities at a time in the following

manner. A cementation or converting furnace, consists of two parallel troughs, constructed of fire-brick, sufficiently long to admit with convenience a common bar of iron; these troughs rest upon a long grate from which flues proceed so as to distribute the heat as evenly as possible to every part: an arched vault is thrown over the top, and the whole is inclosed within a cone of masonry as the glass house furnaces are. The bars of iron intended for cementation are of the very best quality, (in England none but the Swedish Oregrund iron is employed for this purpose) and are carefully examined to ascertain that they are quite free from cracks, flaws, and every appearance indicative of their not being completely malleable. The requisite selection being made, a stratum of coarsely bruised charcoal is laid at the bottom of the cementing trough, upon which is arranged a layer of iron bars: to this succeeds another of charcoal, and so on till the trough is nearly filled, observing that the upper as well as the lowest layer is charcoal: it is then covered with a mixture of hard rammed clay and sand in order to exclude the air. A trough thus charged will contain from seven to ten tons of iron. The fire being lighted, the heat passes into the flues and raises the temperature of the troughs to a glowing red which is maintained for the space of from seven to eleven days according to the quantity of iron. At the extremity of each trough is a small hole, through which two or three bars project a few inches in order that they may be occasionally withdrawn to ascertain the progress of cementation: when by the trial bars, it appears to be compleat, the fire is put out, and after the troughs are sufficiently cool they are emptied of their contents. The form of the bars thus converted, remains unaltered, but their surface is covered over with bubbles or blisters, whence the steel in this state is called *blister steel:* it is heavier than the iron from which it was made

on account of its having absorbed a portion of carbon from the charcoal with which it was in contact, though this is by no means the only action that takes place in the process of steel-making, as we shall show in the next section. Blister steel is employed only for the coarsest purposes, such as pointing horses shoes, ploughs, and other agricultural instruments, &c. By being drawn down into smaller bars under the tilt-hammer, its texture is considerably improved, and it is known in the markets by the name of *tilted steel.* As repeated hammering improves iron, so it does steel: hence if a bar of highly carbonized blister steel, be broken into very short pieces, and these being formed into small packets, are again welded together and drawn down into bars, which being again doubled together are welded and tilted, repeating the process two or three times, the result will be a very material improvement in compactness and toughness, and the metal will be found well qualified for swords and the larger articles of cutlery: this steel has long been prepared in high perfection in Germany, whence it is called *German steel;* it is also known by the name of *Shear steel.*

This is the proper place to mention the process of *Case-hardening*, which in fact is only an imperfect kind of cementation, converting little else than the immediate surface of the metal into steel, and therefore being performed not on the rough bar, but the manufactured article. The cements or carbonaceous substances used on this occasion are bone shavings or turnings, horn cuttings, and old leather shoes. The work intended to be cased, having been previously filed to the requisite shape, that there may be as little occasion as possible to apply the file afterwards, is laid together with the cement in a pan of plate-iron. A forge fire is then made of considerable size, and when the upper part has caked together it is carefully lifted off without breaking, the pan is laid upon the red coals and covered with the caked mass. In this state it remains for near-

ly two hours, without urging the fire. Small pieces of iron wire that have been previously introduced into the pan being withdrawn from time to time, are dipped while hot in cold water, and by the file and the character of the fracture, the progress of the cementation is determined. When the intended degree of carburation is obtained, the fire is increased and the articles as soon as sufficiently heated are taken out of the pan and plunged in cold water. The inferior kinds of table-knives and some surgical instruments, where a considerable degree both of toughness and hardness is required, are prepared in this way.

The finest kind of steel however, called *English cast steel*, yet remains to be mentioned. It is commonly prepared by breaking to pieces the blister steel and then melting it in a crucible with a flux composed of carbonaceous and vitrefiable ingredients. When thoroughly fused it is cast into ingots, which by gentle heating and careful hammering are tilted into bars. By this process the steel becomes more highly carbonized in proportion to the quantity of flux, and in consequence is more brittle and fusible than before; it is inferior to the other kinds of steel in being incapable of welding either with iron or steel, but on the other hand surpasses them all in uniformity of texture, hardness, and closeness of grain, hence it is the material of all the finest articles of English cutlery. The composition of the flux used in preparing this steel is kept a secret among a few manufacturers, and in consequence, various experiments have been instituted both here and elsewhere to discover either the same or an equally successful method of making this beautiful substance. In 1795, Clouet published the results of some valuable experiments, from which it appears that by simply fusing bar iron with charcoal, a cast steel may be obtained more or less carburetted, according to the proportion of charcoal employed, and therefore possessing at pleasure in

greater or less degree the qualities of fusibility, brittleness, and hardness; he also showed that the same effects may be produced by fusing bar iron with glass and charcoal, or the black oxide of iron with the requisite proportion of charcoal alone, or by keeping in fusion for about the space of an hour a mixture of small bits of iron and equal parts of clay and marble or any other calcareous carbonat. In 1800, Mr. Mushet took out a patent for preparing cast steel of various qualities by fusing bar iron with different proportions of charcoal, coinciding (?) for the most part with the facts and principles before laid down by Clouet, and confirmed by his own experiments; but whether the steel thus prepared is equal to the finest cast steel of Huntsman, has not, we believe, been as yet completely ascertained.

Steel is rendered hard by heating and then suddenly cooling it. The degree of hardness which it is capable of acquiring is in direct proportion to its fusibility, or in other words to the quantity of carbon with which it is combined; and the degree of hardness which in any particular instance is actually given to it, is in proportion to the difference of temperature between the medium in which it is heated and that in which it is cooled; modified however by the capacity for heat, and the conducting power of the cooling medium. Thus if steel is heated somewhat below the degree at which it melts and then transferred into oil at the temperature of 200°, the hardness thus acquired will be inferior to that which would have been obtained if water, or still more so if mercury, at the same temperature had been made use of. Again, if instead of oil at 200° the same fluid at 400° had been employed, a greatly superior degree of hardness would have been produced.

The hardness acquired by this method has generally been thus accounted for. The particles of the metal by

being heated are placed at a greater distance from each other than before, and in proportion as this heat is again abstracted, the attraction subsisting between them will become efficacious, and they will approach nearer to actual contact; but the impetus with which this takes place will be in proportion to the difference of temperature, and therefore when red-hot steel is plunged in ice-cold mercury, the force or resilient spring of its particles will be greater than if mercury at 200° had been made use of, and consequently its hardness will also be greater. But this theory however ingenious is opposed by certain facts which perhaps may be found more consonant with the following explanation of them.

If we take the specific gravity of a piece of steel both when hardened, and after it has been softened by heating again and gradually cooling, we shall find that its bulk in the former case is greater than in the latter; whereas if the hardness of steel was owing to the rapidity and energy with which its particles collapsed on cooling, directly the reverse of this ought to take place, the state of greatest hardness should be that of the greatest specific gravity. So in like manner we find to be the case with glass; if a little of this in a melted state is dropped into cold water it will prove very hard and brittle; but if the same piece is again heated red (without however in any degree softening it) and afterwards allowed to cool gradually, its specific gravity will have very notably increased, and it will have become tough and elastic. We may therefore consider the hardening of steel to be caused by the contemporaneous expulsion of part of its heat and the fixation of its particles before they have had time to arrange themselves and contract upon each other. Hence on the impression of any external force, the particles that are struck are not able to slide on each others surfaces, and thus distribute the impetus which they have received over the contiguous

ones; or in other words the mass becomes *harder* than it was before, hence also the whole force of a blow is borne by a comparatively small number of insulated particles, and these entirely giving way before a degree of percussion that might easily be sustained by the whole when combined, thus produce the quality of *brittleness*.

If highly carburetted steel is made nearly as hot as it can bear without melting, and is then plunged in very cold water, it is apt to fly to pieces, and even if this does not take place, the metal is not applicable to any use in this state of extreme hardness, for the particles are placed so far asunder, that the whole has a strong tendency to become crumbly, and will not bear a fine, even, sharp edge. In the practice of the best manufacturers, the hardening heat even for files, which are the hardest of all steel instruments, is not greater than a red visible by day-light; and all cutting and elastic instruments require to be much softer. The various degrees of hardness necessary for different articles are not however given, as might at first be supposed, by the simple process of hardening at the requisite temperature, but by the compound method of first giving to every article nearly a file hardness, and then, by the subsequent process of *tempering*, reducing the hardness to the particular degree necessary for each article.

Tempering consists in softening hardened steel by the application of a heat not greater than that which was employed in hardening it; for this purpose it is gradually heated more or less according to the temper required, and cooled again either gradually or rapidly, this making no difference; after which the steel is found to be softened or tempered exactly in proportion to the heat which it has undergone. While the steel is tempering, its surface displays a succession of colours (supposed to arise from a commencing oxydation) in proportion as it becomes

more and more heated, which the workmen in this metal have ingeniously taken advantage of, as indicating and serving to denominate the degree of temper required for different articles. The first perceptible colour is a light straw yellow, and this being produced by a small degree of heat indicates the highest or hardest temper; to this succeeds a full yellow, then a brown, afterwards a reddish blue, then a light blue, and lastly a full deep blue passing into black, which being the other extremity of the series, denotes the lowest degree of temper, and a hardness only a little superior to what the piece of steel would have acquired if when heated for the purpose of being hardened it had been allowed to cool gradually instead of being plunged into a cold liquid. The old method of tempering, and which indeed is still practised by most manufacturers, is to lay the articles on a clear coal fire, or on a hot bar, till they exhibit the requisite colour; but small articles which were to be reduced to a blue temper were commonly *blazed*, that is they were first dipped in oil or melted grease, and then held over a fire till the oil became inflamed, and thus evaporated.

Some particular articles require a nicety of temper that is not very easily attained by trusting merely to the change of colour, a circumstance that induced Mr. Hartley, in the year 1789, to take out a patent for a new and more accurate method. For this purpose a mercurial thermometer graduated as high as 600° is to be immersed in an iron trough heated by a furnace or lamp placed below it, and filled with fusible metal, upon the surface of which the steel is to be laid, which may thus be tempered with great accuracy at any degree of the thermometer that the artist chuses. Oil may be substituted to the fusible metal, and the effect will be the same, except that the steel being in this case tempered beneath the surface of the liquid, and of course out of the contact of atmospherical air,

will not exhibit those changes of colour which take place when the other methods are employed. The following table shows the temperature at which the various colours make their appearance.

430° to 450° indicates the several tints of straw colour, and is the temper for razors and those intruments which have a stout back supporting a keen and delicate edge.

470° corresponds with the full yellow, and is the proper temper for scalpels, pen-knives, and other fine-edged instruments.

490° indicates the brown yellow, and is the proper temper for scissars and small shears.

510° indicates the first tinge of purple, and is the temper for pocket and pruning-knives.

530° indicates purple, and is the temper for table and carving-knives.

550° to 560° indicates the different shades of blue, and is the temper for watch-springs, swords, and all those instruments in which great elasticity is required.

600° corresponds with black, and is the lowest degree of temper.

One great advantage attending the use of cast steel is its uniform quality: the carbon which it contains appears to be equally distributed through every part of the same mass in consequence of the fusion that it has undergone: whereas both the natural steel and the steel of cementation, are apt to contain veins of iron, either quite soft or at most very slightly carburetted, and thus a degree of imperfection and uncertainty is introduced extremely mortifying to the artist, and not unfrequently the occasion of much labour in vain. It is therefore no small benefit which Mr. Nicholson has conferred on the workers in iron and steel by publishing a simple and effectual method of ascertaining whether any particular bar is pure iron or steel or a mixture of both. The surface of the metal being cleaned

with a file or with emery paper, is to be spread over with very dilute nitrous acid, by which the iron will be dissolved, but the carbon will remain behind untouched; after therefore the acid has been allowed to act for a few minutes, the bar is to be put into clean water and moved about in it gently, that both the residual acid and the nitrat of iron may be washed away, care being taken not to touch the surface with the hand or any thing else that may rub off the carbon. The bar thus washed, if pure iron, will exhibit an uniform iron-grey colour; if it be pure steel, the colour of the surface will be black, the iron having been taken up by the acid and a thin coating of carbon remaining; but if it be a mixture of iron and steel, the surface will be dotted or streaked, those parts which are steel being of a dull black, and those which are iron exhibiting the usual colour and lustre of this metal.

Steel being considerably more expensive than iron, it is customary in making the larger and coarser kinds of cutting instruments to form only the edge of steel. The two bars of iron and steel are first welded together and afterwards forged into the requisite shape in the usual manner. Highly carbonized steel is however incapable of being thus united to iron, because the same temperature at which iron welds freely, is that, at which this kind of steel enters into fusion, and therefore the first stroke of the hammer will entirely shatter the steel and disperse it about in small fragments. This however is a difficulty which it is well worth while taking some pains to overcome, as the efficacy and durability of instruments thus composed materially, depends upon the goodness of the steel. The most effectual way hitherto discovered of uniting together iron and highly carbonized steel, is that published by Sir Thos. Frankland. The iron is to be raised to a welding heat, in one forge, and the steel is to be made as hot as it can bear without becoming very brit-

tle, in another; both pieces are then to be quickly brought to the anvil and made to adhere together by gentle hammering.

Several curious pieces of work are made of iron and steel welded together, especially the real Damascus sword blades, which are believed to be composed of slips or thin rods of iron and steel bound together with iron wire, and the whole firmly cemented together by welding. The properties and external appearance of such a blade, correspond very exactly with the supposed mode in which it is manufactured. Its colour is a dull blueish grey, it is scarcely harder than common steel from the forge, it is not easily bent, and when bent has no elasticity to recover its original figure; but the circumstance which principally characterizes it is the appearance of narrow waving lines not crossing each other and chiefly running from heel to point; they are ill-defined and about the thickness of a harpsichord wire. This wavy appearance is not produced by any perceptible indentation of the surface, but merely by a slight difference in the degree of polish or brightness, and therefore may be at once distinguished from the false damasking or etching by which other sword-blades are made to resemble the genuine Damascus ones. In the false Damascus blades, the waving lines, called the *water*, are obliterated by grinding, but in the real ones, although the water is at first imperceptible after grinding, yet it may at any time be made to re-appear by rubbing the blade with lemon juice, no doubt on account of the unequal action of this weak acid on a surface composed both of steel and iron.

Besides the varieties of steel that we have already described, there yet remains one more, concerning which a few words will be necessary: this is Wootz. The substance known by this name in India, is imported into this country in the form of round flat cakes about five inches

in diameter and one inch in thickness. When cold it is uncommonly refractory, neither breaking nor bending under the hammer. It is not nearly so easy to be filed as either bar or cast steel before these have been hardened: it takes an extremely high brilliant polish; its fracture is moderately close, resembling that of blister-steel that has been heated and hammered a little. When nearly white hot it is malleable, but is much more likely to crack under this treatment than even cast steel; it requires therefore much care, labour, and time to fashion it into any required shape. When made white hot, it exhibits the glassy smooth surface of welding iron, but when struck very gently with a hammer, it cracks in many places, and by a harder blow is shivered to pieces. When brought to a high heat and quenched suddenly in cold water, it becomes harder than at first, though not equally so with the finest cast steel in similar circumstances; but on the other hand, it is not capable of being sensibly softened by annealing as the other varieties of steel are. At a high heat it is fusible, and after being melted exhibits a close compact grain, is considerably brittle, and bears a very near resemblance to cast steel. From its analysis and other circumstances, it is considered by Dr. Pearson as differing from steel, only in containing a little oxyd of iron.

Comparison and analysis, of Cast Iron, Bar Iron, and Steel.

Notwithstanding the close attention of various eminent chemists to this important subject, much yet remains to be done before an entirely satisfactory theory can be formed to account for the different properties possessed by the various kinds of iron and steel. We shall endeavour to show in the present section, the progress that has already been made in this interesting analysis, and shall then point out some of the chief difficulties that yet remain to be overcome.

In all the varieties of iron and steel, the principal ingredient is metallic iron, and as this metal in the reguline state alone, has the property of giving out hydrogen gas while dissolving in dilute sulphuric or muriatic acids, the amount of inflammable gas thus produced has been adopted by Bergman, by Berthollet, and Pearson, as upon the whole the most satisfactory and compendious exponent of the quantity of reguline iron contained in any of the known varieties and forms of this metal. Thus a mixture of equal parts of reguline and oxydized iron by treatment with dilute sulphuric acid, will produce only half the quantity of hydrogen gas that an equal weight of pure iron would. But this can be admitted to be a perfectly accurate mode of proceeding, only where the mixture thus analyzed, contains nothing that is soluble in hydrogen gas at the temperature, and in the other circumstances under which the experiment is performed. None of the kinds of manufactured iron is entirely free from carbon, and this according to Berthollet is taken up by the nascent hydrogen as the metal dissolves in the acid, whence originates a material source of error, the quantity of gas produced depending not merely on the proportion of iron, but also of carbon in the mixture. It appears from Berthollet's experiments that when cast iron or steel is treated by dilute sulphuric acid, at a boiling temperature, in proportion as the metal dissolves, a black spungy matter is observed floating in the solution : the quantity of this increases till the process is about half over, then it begins to diminish, and will be found to have entirely disappeared by the time that the last portions of iron have dissolved. This black matter is carbon, which being insoluble in sulphuric acid or sulphat of iron, must necessarily have been taken up by the hydrogen. This accordingly is found to be the case, for the gas produced requires a greater proportion of oxygen for its combustion, and the result of

the process is a quantity of carbonic acid. This is further confirmed by an observation of Rinman's that the inflammable gas arising from the solution of steel, affords by combustion more fixed air than that which is produced from the solution of bar iron. From the numerous experiments of Berthollet on this subject, we have selected the six following as sufficient for our purpose, and having converted the weights and measures into English, it appears that at 29.84 Bar. and 59° Fahr.

Grs.	measures of inflammable gas.	
100 of grey cast iron yield with diluted sulphuric acid	104.8	oz.
100 of bar iron made from the preceding - -	111.5	do.
100 of Steel from the preceding - -	108.3	do.
100 of Swedish bar iron - - -	114.	do.
100 of Steel from the preceding - -	106.7	do.
100 of white cast iron from Eisenerz - -	97.4	do.

It might at first be supposed that a given quantity of hydrogen would increase in bulk in proportion to the carbon taken up by it, the reverse of this however is in fact the case: therefore if Swedish bar iron be considered as the pure state of this metal, represented by the number 114, the proportion of iron contained in an equal weight of steel made from the same will be more than 106.7, because the former number indicates pure hydrogen, but the latter carburetted hydrogen.

Dr. Pearson on the other hand, in his experiments on Wootz, assures us that when dilute sulphuric acid is acting on steel at the common temperature, a quantity of black carbonaceous matter is separated, which continues to augment so as to impede the effect of the acid; if at this period a lamp is applied, the increased temperature brings on a more rapid action, and the black sediment appears rather to diminish in quantity. This diminution however Dr. P. attributes only to the solution of the iron with which the carbon was combined, and not to the solution

of the carbon itself in the hydrogen: for, says he, the gas when burnt with oxygen procured from manganese, inflamed like common hydrogen, and whether procured by means of iron, or steel, or wootz, produced only a very slight turbidness with lime-water; whereas carburetted hydrogen, prepared by passing steam through hot charcoal, being treated in the same manner, rendered the lime-water quite milky. The proportions of gas from iron and steel were also remarkably less than those mentioned by Berthollet. 100 grains of wootz, by several experiments, yielded from 78 to 84 ounce measures of gas. 100 grains of steel wire, also by various experiments, yielded from 83 to 86 ounce measures of gas. 100 grains of iron wire yielded from 86 to 88 ounce measures.

How much soever the experiments of Berthollet and Dr. Pearson differ in other respects, yet we may infer that Swedish bar iron contains a larger proportion of reguline iron than the other varieties of bar iron, that steel contains a smaller proportion than bar iron, that wootz contains a still smaller proportion, that grey cast iron is inferior in this respect to steel, and that white cast iron is the least pure of any.

We also learn that the lower the temperature is at which the solution of the iron is made, the purer is the hydrogen that is produced, and with proper care that the objections raised by Berthollet to the accuracy of this mode of proceeding, may be completely done away. (? T. C.)

We have already mentioned that almost all the known varieties of iron and steel contain a larger or smaller proportion of carbon. The quantity of this in any particular sample of metal may best be ascertained by digesting the metal in dilute nitro-muriatic acid, which will leave untouched the carbon united with a little iron. This black insoluble residue being washed in warm water and

finally digested for a minute in weak ammonia, should be heated in a flask almost to redness, to expel the water and any muriat of ammonia that it may contain; being then weighed, it is to be ignited in a silver or platina crucible till the whole of the carbon is burnt off, and the residual iron is oxydized: from the weight of this oxyd is to be deducted 48 per cent. on account of the oxygen, and the difference between the weight of the remainder and that of the black powder before ignition indicates the amount of carbon.

The affinity of iron for carbon is pretty considerable, though it is by no means capable of decomposing carbonic acid by combining with its base, as Mushet has clearly shown in opposition to the assertion of Clouet.

The effects produced upon iron by carbon are very remarkable. First with regard to colour: the blueish grey tint of iron becomes more and more white in proportion as it combines with carbon, till it possesses almost a silvery colour and lustre, as is the case with the white cast iron in which state the metal seems to be saturated with carbon. At the same time that these changes of colour are going on, the tendency to crystallization is rapidly increasing, hence the fracture from being fibrous and hackly, becomes first compact, then granular, and at length exhibits facets like antimony. With these changes the fusibility increases, and the faculty of welding diminishes, and soon entirely ceases: the ductility and malleability also undergo an analogous change, though not quite to so great an extent: the hardness increases, as also does the property of induration by sudden cooling, and the capability of being tempered.

Iron however may not only be saturated but supersaturated with carbon: that is to say, when at a very high temperature it will dissolve more carbon than it can hold in solution at a lower temperature; and in consequence,

by slow cooling while it is still fluid, a part of this excess of carbon will separate from the rest of the mass and rise to the surface, forming a flasky crust of plumbago or carburet of iron. Some however of the plumbago will still remain enveloped by and dispersed through the iron, giving it an uniform dark grey or black colour if the proportion is considerable, or only mottling it if the excess of this substance is very slight.

The actual proportions of carbon contained in the different kinds of iron have not yet been ascertained with any accuracy either by analysis or synthesis; but thus much appears certain, that bar iron in general contains a smaller quantity than the softer varieties of steel, and these again always contain less carbon than the common and finer cast steel; that in the white, the mottled, the grey, and the black varieties of cast iron, the dose of carbon is constantly augmenting, in the last of which the proportion of carbon is probably about $\frac{1}{20}$ of the whole.

Oxygen is also contained in most of the varieties of iron, and the effects occasioned by it in the different processes to which this metal is subjected, require more attention than has hitherto been paid to them. Cast iron appears to be highly charged with oxygen, and on this account requires to be supersaturated with carbon in order to be converted with any economy into bar iron. It may seem at first a paradox to maintain the co-existence of oxygen and carbon in the same metallic mass, especially considering the great heat to which it is exposed in the process of reduction, since it is an universal and uncontroverted fact, that metallic oxyds are decomposed by carbon at a high temperature, the oxygen and carbon uniting together and being dissipated in the form of gas, the metallic regulus remaining behind. But when the roughness of the smelting process in blast furnaces, and the large quantity of materials operated on at once, as well as the great

pressure of the superincumbent scoriæ are taken into consideration, we shall cease to be surprised at the apparent anomaly. The existence of oxygen in cast iron, is manifest from the phenomena that accompany the operation of *puddling* as already described in a preceding section. The crude iron being subjected to a high temperature, under a pressure no greater than that of the atmosphere, the oxygen and carbon that it contains react upon each other and produce carbonic acid and gaseous oxyd of carbon, which having escaped, the metal is found reduced to a state of malleability. The same effects take place in close vessels, as Dr. Beddoes has well shown. If crude cast iron is put into a retort, as soon as the vessel and its contents have acquired a low red heat, an inflammable gas, mixed with carbonic acid, is given out with considerable rapidity (this inflammable gas must, from the circumstances, be the oxyd of carbon) when the production of gas ceases, the iron upon examination will be found to have lost somewhat of its weight, and to be nearly in the state of bar iron. But though this combination of the oxygen and carbon of the crude metal, and the consequent generation of air takes place with great ease when the beak of the retort is but just dipped under water, yet if the pressure amounts to five inches of water, in addition to the atmosphere, the disengagement of air proceeds very slowly, and entirely ceases if instead of the water, a single half inch of mercury is employed; although upon removing this obstacle the bubbles of air pass through as before.

By the treatment that cast iron undergoes during its conversion into malleable bar iron, the greater part of the oxygen and carbon is got rid of; still, however, a small quantity of oxygen, the smaller in proportion to the goodness of the iron, remains. This is inferred with much probability from the blistered appearance that the bars of

iron exhibit after having been converted into steel by cementation. These blisters are manifestly occasioned by the exudation of a gas from the bar, and this gas in all probability is oxyd of carbon. A further proof of the existence both of oxygen and carbon, even in Swedish bar, may be deduced from some interesting experiments by Mr. Mushet. Having put some pieces of Swedish bar iron into an earthen crucible, with a flux composed of marble and calcined clay, he observed first, that the earths melted together before the iron showed signs of fusion, and that while this latter was melting, bubbles of air were continually rising from it and passing through the vitrified flux: this gas burnt with a lambent blue flame, and probably was gasseous oxyd of carbon: the iron sustained a notable loss of weight, and had become considerably softer than at first.

Steel probably is entirely free from oxygen.

The action of vitrescent earthy mixtures comes next to be considered. It is certain that cast iron contains a very considerable proportion of scoriæ diffused through its substance, which are partly got rid of by subsequent fusion, as they rise to the surface of the metal, being considerably lighter than it, while such portions as still remain are got rid of, for the most part, by hammering and laminating during the conversion of the cast iron into bar. A very small proportion of scoriæ, however, is not unfrequently left in the iron, as is obvious from the earthy residue that some of the varieties of this metal leave behind them when dissolved in acids. It is not yet clearly made out what is the precise effect of a little earth on the malleability of iron. Clouet has endeavoured to show that it renders the iron softer and more malleable, but inclined to be hot short, and the experiment by which he demonstrates it, is the fusing together of iron and glass, by which the effects just mentioned are produced upon the metal.

But this is precisely the same experiment as that of Mr. Mushet's, related in the preceding paragraph, and M. Clouet having entirely overlooked the extrication of gas from the metal, has gratuitously attributed the change produced to a combination of the iron with a little of the glass, without, as appears, taking the trouble to substantiate his hypothesis by actual analysis.

Cast iron made with coke instead of charcoal, must necessarily contain a variable proportion of sulphur: nor is this substance very likely to be entirely dissipated by the subsequent refining that the metal goes through; and it appears from a direct experiment by Dr. Beddoes, that iron after being puddled and stamped, if treated with muriatic or sulphuric acid, will give out sulphuretted hydrogen. Bergman has shewn that certain varieties of iron contain manganese, and others phosphoric acid. Clouet has detected arsenic in some; and other chemists have somewhat obscurely intimated the presence of lead, copper, and zinc, which is far from improbable, as several of the ores of iron are occasionally mixed with galena, copper pyrites and blende. But the effect of these substances in small quantity on iron has not yet been ascertained by any experiments that can be depended on; it is therefore obvious how much remains to be done before we acquire a thorough knowledge, even on practical points, of this most important of all metals.

The following, in the present state of our researches on this subject, may be laid down as the essential characters of the principal forms under which iron exhibits itself. Crude cast iron, besides casual impurities contains carbon, oxyd of iron, and vitrified earth. The difference between white, mottled, grey and black cast iron depends on the proportion of carbon, which is smallest in the white and greatest in the black. By the process of refining or re-smelting, most of the earth and oxyd of iron rises to the

surface of the metal in the form of a dense slag; hence the residual iron differs from the crude pig-metal in containing less earth and oxyd. By the subsequent operations the carburet and oxyd of iron mutually decompose each other, forming carbonic acid and carbonous oxyd, by which the metal is freed both from its oxygen and carbon. In this state it forms bar iron, which may or may not retain a small proportion of vitrified earth, but which seems even when purest to hold a little both of carbon and oxyd. If this bar iron is exposed in a close vessel to a high heat, the carbon and oxygen that it contains (if they are in due proportion to each other) will be entirely got rid of, the metal will become very soft, and will be at the same time malleable and fusible. If the bar iron instead of being heated by itself has access to carbon either in the state of charcoal or plumbago, its oxygen will be expelled and carbon will at the same time be absorbed: if the portion of this latter be small, the mixture will partake of the properties both of iron and steel, hence it will be very malleable and capable of being welded, but also will be harder than pure iron, somewhat more fusible and susceptible of being tempered. By being united with a fresh portion of carbon it will become still more fusible and will lose its welding property; it will become harder, more compact, and will form the fine cast steel. A further portion of carbon increases the brittleness and hardness, so as to render it incapable of being wrought, and its colour and texture will approach to that of white cast iron: in this state it may be regarded as saturated with carbon. It is however capable of uniting to this substance even to supersaturation, by which its colour and texture resembles that of grey or black cast iron; its fusibility is somewhat increased but its hardness is so much lowered by this excess of carbon as to allow it to be wrought with ease by a common file, nor can it be materially hardened by sudden

cooling or be tempered, so that it is no longer in the state of steel. By a still further cementation with charcoal it would in all probability be converted into plumbago.

Many chemists have supposed that supercarbonized steel is the same thing as crude iron, because they resemble each other in their fracture and colour and contain carbon; and upon this reasoning have been founded several imperfect and ineffectual methods of applying the finer kinds of cast iron to some of the uses of common cast steel; but we have shewn that however great may be the resemblance in some points, yet cast iron essentially differs from steel in containing both earth and oxyd of iron, and therefore cannot be substituted for it with any success.

It only remains to say a few words concerning two states of bar iron called *hot-short* and *cold-short*.

Iron that is hot-short or red-short is very soft and ductile when cold, on which account it is generally employed in the manufacture of wire; it may also be hammered and welded if treated skilfully at a full white heat, but when it has cooled down to a cherry red, it breaks away before the hammer and is dissipated almost like sand.

Cold-short iron on the contrary is harder not only than hot-short but also than pure Swedish bar iron; it may be wrought in the usual way when red or white hot, but possesses no toughness when cold; so that a large bar may with ease be broken across by a common hand hammer.

Hot-short iron is imagined, rather than proved, to contain arsenic, to which its brittleness at a red heat is supposed to be owing.

Cold-short iron is supposed by Bergman to derive its characteristic qualities from a portion of phosphoric acid; and it is certain that phosphat of iron has been found in

iron of this description, both by the illustrious Swedish chemist just named and Meyer and Clouet.

If however it be granted that hot-short and cold-short iron respectively contain arsenic and phosphoric acid, yet it must in return be allowed that these qualities appear in very many cases where there is no reason to suspect either the one or the other, and that the methods by which these defects may be produced or remedied are in many cases at least not very reconcilable with their supposed origin.

If white cast iron, that is, such as is deficient in carbon, be exposed to the action of a current of flame after it has exhibited its proper degree of malleability, it will pass into the state of cold-short iron, and its brittleness will increase in proportion to the length of time that it is thus exposed. Does it not therefore seem probable that in many cases at least the defects of cold-short iron are occasioned by an absorption of oxygen? This however the advocates for the universality of Bergman's theory on this subject may allow with perfect consistency. They would say that the phosphat of iron originally contained in the ore is converted by the process of smelting into phosphuret of iron, which being capable of uniting perfectly with bar iron and forming only a very small proportion of the whole may render the iron hard without materially impairing its toughness while cold: but when this iron deprived of carbon is exposed at a high temperature to the action of the air, the phosphorus becomes acidified, and the phosphat of iron that hence results being incapable of combining with malleable iron is merely dispersed through it, and must therefore tend to render it brittle. Nor is the explanation of the fact contradicted by the methods made use of to correct this quality. Rinman says that cast iron which by the common treatment would yield cold-short bar, may be made to afford soft malleable iron by fusing

it with a mixture of equal parts of lime and scoriæ. Mr. Mushet says that 875 grains of cold short iron when melted by itself in a covered crucible formed a perfect button covered by a thin film of brown glass. The metal weighed only 805 grains, and instead of being cold-short, was now found to have acquired the opposite fault of being hot-short, it was extremely soft and ductile. In these experiments it may be said that the metal being brought to a state of quiet fusion, the phosphat of iron either entirely or at least for the most part separated in the form of glass from the reguline portion. But as all the above phenomena may be accounted for equally well upon the supposition that the cold-short quality is owing simply to the mixture of oxyd of iron with the metal, it would be useless to speculate further on the subject till a sufficient number of accurate analyses have been performed to direct our investigations. The hot-short quality appears to be occasioned by the admixture of some substance which enters into fusion at a low red heat, and thus destroys the tenacity of the iron through which it is diffused: hence this variety of iron cannot bear the hammer at a red heat, though when the temperature is raised to the full welding point, the effect of this unknown substance is counteracted by the tenacity which the particles of iron then acquire. This substance has been by some supposed to be carbon, but this is inconsistent with the extreme softness which always characterises hot-short iron: for the same reason it cannot be phosphorus. The effects are more like those of a metallic body; and lead, arsenic, copper, and zinc may be each suspected with almost equal probability. In some varieties of hot-short iron, especially those made with coke, the fragility increases with the increase of temperature, and they are wholly incapable of welding: this probably arises from a large admixture of the same substance, whatever it be, to which

the more usual characters of hot-short iron are owing, with perhaps a little sulphur.

Physical properties of Iron and Steel.

Iron whether in the states of cast or bar iron, or steel, is attractable by the magnet, and capable of acquiring polarity, this last property however is more durable and powerful in steel than in any of the other forms of this metal.

Supercarbonized cast iron is of a dark grey almost black colour, has a granular fracture, is very brittle, is more fusible than the other kinds of cast iron, and yields without difficulty to the file. White cast iron is of a tin-white colour, and a coarse grained fracture; it is brittle but very hard, and less fusible than the preceding variety. The grey and the mottled varieties approach nearer to the one or the other in proportion to their colour. The specific gravity of cast iron has not been ascertained with great exactness, and no doubt is subject to some variations: that which is most highly carbonized has the least specific gravity, nor does it probably ever much exceed 7.01. Cast iron takes impressions from moulds with much more sharpness and precision than any other metal: and when in fusion if pieces of cast iron are thrown in, they will be observed to float on the surface till they melt and mix indistinguishably with the rest; hence it has been generally acquiesced in that melted cast iron is of greater specific gravity than when solid; contrary to what takes place in all the other metals. This however seems to be founded on a mere fallacy, for if it were true, the iron when poured into a mould and beginning to solidify, ought to spirt out part of the melted metal, as water does under similar circumstances when converting into ice: whereas on the contrary, a considerable contraction happens which obliges the workmen who are employed in casting large pieces, to fill the runners or channels into the mould with melted metal, lest any cavities should be

formed in the piece and thus spoil it. Further, this contraction is so well known, that when castings of particular dimensions are required, the mould is constantly made larger than the pattern by $\frac{1}{96}$ or sometimes $\frac{1}{64}$, to allow for the shrinking. Now it is impossible that this should happen if the specific gravity of the melted metal really exceeded that of the solid metal: how then does it happen that the solid will float on the fluid metal? the answer to this is not perhaps very obvious; but it may be remarked that not only solid cast iron but even bar iron which is of considerably greater specific gravity, and not only bar iron but even lead which is more than half as heavy again as cast iron, will float upon its surface. But though cast iron like all other metals shrinks when it becomes solid, yet at the instant of congealing it appears to undergo a momentary expansion, and thus takes a remarkably perfect impression of any pattern with which it comes in contact.

Bar iron is of a bluish white colour, has a fibrous hackly fracture, is malleable both when hot and cold, and is capable of uniting with another piece of bar iron by welding: it may be drawn into very fine wire and is the most tenacious of all metals, a wire $\frac{1}{10}$ of an inch in diameter being capable of sustaining from 450 to 500lbs. before it breaks. It is fusible, but requires for this purpose a higher heat than cast iron. Its specific gravity is subject to some variations: that of common hammered iron, according to Dr. Pearson, is from 7.45 to 7.6: Swedish bar iron varies between 7.70 and 7.78. It expands like all other metals by heat: the amount of its expansion for every degree of Fahrenheit's thermometer between the freezing and boiling point of water, is equal to 0.000006358.

Steel is of a light-grey colour and a fracture more or less fine granular: it is harder and more brittle than bar iron in proportion to the quantity of carbon that it con-

tains; when slightly charged with this substance it is malleable, ductile, weldable and elastic, but when more nearly saturated with carbon it is not capable of being welded, and its fusibility is increased. It may be hardened by sudden cooling, and may afterwards be made softer by tempering. Its specific gravity varies much: that of the best blistered steel before hammering is =7.31, of the same after hammering =7.73: of very hard steel =7.26: of melted steel wire =7.5: of English cast steel hammered, from 7.82 to 7.91.

Report concerning the Art of making fine Cutlery—From 4 Nicholson's Journal, quarto, page 127.

The fabrication of edge tools is one of the first arts among men in every state of society. Artizans are well aware of the necessity, that the instruments of their respective trades should be made to possess the qualities adapted to the operations by which they gain their subsistence; and among the various sub-divisions of labour, there is perhaps no material, upon which the skill and judgment of practical men are more multifariously exercised than steel. The makers of files, of chissels, of planes, saws, and the infinite variety of knives, all occupy their several departments separate from each other, and possess their respective degrees of celebrity among workmen, which are grounded on their knowledge of the peculiar kinds of steel, as well as the methods of working them, which are best suited to the intended operations. Many of these methods are kept secret; but in general the philosophical enquirer will find the communications of operative men, to the full, as liberal and open as the circumstances of the case may seem to warrant. Many manufacturers have no reserve with regard to the manipulations of their art, and have the spirit to assert their claims to public encouragement, upon the open ground

of the address and integrity with which they conduct their professional labours.

Among the instances of this kind which have occurred to me during a life of diligent enquiry, I have lately been much gratified by the ready assistance and communications of Mr. Stodart of the Strand, which enable me at present to communicate my own notions on the subject of fine cutlery, with the advantage and support of his successful experience; which I shall proceed to do without further preface.

It appears to be at present generally agreed, that for all works which do not require welding, cast steel is preferable to any other. For fine cutlery it undoubtedly is. Mr. Stodart uses those bars which are marked Huntsman, but does not suppose it to be of a better quality than that of Walker, and other manufacturers. He complains, that it is much worse in quality now than formerly, which complaint I have also heard from other intelligent artists. I did not ask him concerning the art of forging, but take it for granted, that it consists in little more than the acquired skill of managing the bar and the hammer, with the precautions not to injure the texture by strong hammering at too low a heat, or to degrade the quality of the steel, by too much heat or exposure to the current of air from the bellows.

Cutlers do not use any coating to their work at the hardening heat, as the file cutters do; and indeed it seems evidently unnecessary when the article is intended to be tempered and ground. Mr. S. agrees with me, that the best rule is to harden as little as possible above the state intended to be produced by tempering. Work which has been overheated has a crumbly edge, and will not afford the wire hereafter to be described. The proper heat is a cherry red visible by day-light. He has not found that any advantage is obtained from the use of salt in the water,

or cooling that fluid, or from using mercury instead of water; but it may be remarked, that questions respecting the fluid, are, properly speaking, applicable only to files, gravers, and such tools as are intended to be left at the extreme of hardness. Yet though Mr. Stodart did not seem to attach much value to peculiarities in the process of hardening, he mentioned it as the observation and practice of one of his workmen, that the charcoal fire should be made up with shavings of leather: and upon being asked, what good he supposed the leather could do, this workman replied, that he could take upon him to say, that he never had had a razor crack in the hardening since he had used this method, though it was a very common accident before.

One of the greatest difficulties in hardening steel works of any considerable extent, more especially such articles as are formed of thin plates, or have a variety of parts of different sizes, consists in the apparent impracticability of heating the thicker parts, before the slighter are burned away; besides which, even for a piece of uniform figure, it is no easy matter to make up a fire which shall give a speedy heat, and be nearly of the same intensity throughout. This difficulty formed a very considerable impediment to my success in a course of delicate steel work, in which I was engaged about seven years ago; but after various unsuccessful experiments, I succeeded in removing it by the use of a bath of melted lead, which for very justifiable reasons has been kept a secret till now. Pure lead, that is to say, lead containing little or no tin, is ignited to a moderate redness, and then well stirred. Into this the piece is plunged for a few seconds; that is to say, until when brought near the surface that part does not appear less luminous than the rest. The piece is then speedily stirred about in the bath, suddenly drawn out and plunged into a large mass of water. In this man-

ner a plate of steel may be hardened so as to be perfectly brittle, and yet continue so sound as to ring like a bell; an effect which I never could produce in any other way. Mr. Stodart has lately made trial of this method, and considers it to be a great acquisition to the art, as in fact I found it.

The letting down, or tempering of hard steel, is considered as absolutely necessary for the production of a fine and durable edge. It has been usual to do this by heating the hardened steel, till its bright surface exhibits some known colour by oxidation. The first colour is a very faint straw colour, becoming deeper and deeper by increase of heat, to a fine deep golden yellow, which changes irregularly to purple, then to an uniform blue, succeeded by white and several successive faint repetitions of these series. It is well known, that the hardest state of tempered instruments, such as razors and surgeons instruments, is indicated by this straw colour; that a deeper colour is required for leather cutter's knives, and other tools that require the edge to be turned on one side; that the blue which indicates a good temper for springs, is almost too soft for any cutting instrument except saws, and such tools as are sharpened with a file; and that the lower states of hardness are not at all adapted to this use. But it is of considerable importance, that the letting down or tempering, as well as the hardening, should be effected by heat equally applied, and that the temperatures, especially at the lower heats, where greater hardness is to be left, should be more precisely ascertained than can be done by the different shades of oxidation. Mr. Hartley first practised the method of immersing hard steel in heated oil, or the fusible compound of lead five parts, tin three, and bismuth eight. The temperature of either of these fluids may be ascertained in the usual manner, when it does not

exceed the point at which mercury boils: and by this contrivance the same advantages are obtained in lowering the temperature of an whole instrument, or any number of them at once, as have already been stated in favour of my method of hardening. Oil is preferable to the fusible mixture for several reasons. It is cheaper; it admits of the work being seen during the immersion by reason of its transparency; and there is no occasion for any contrivance to prevent the work from floating.

I requested Mr. Stodart to favour me with an account of the temperatures at which the several colours make their appearance upon hardened steel; in compliance with which, he made a series of experiments upon surgeons needles hardened, highly polished, and exposed to a gradual heat while floating at the surface of the fusible mixture. The appearances are as follow:

No. 1. taken out at 430° of Fahrenheit. This temperature leaves the steel in the most excellent state for razors and scalpals. The tarnish, or faint yellowish tinge it produces, is too evanescent to be observed without comparison with another piece of polished steel. Instruments in this state retain their edge much longer than those upon which the actual straw colour has been brought, as is the common practice. Mr. S. informs me, that 430° is the lowest temperature for letting down, and that the lower degrees will not afford a firm edge.

No. 2 at 440°, and 3 at 450°. These needles differ so little in their appearance from No. 1, that it is not easy to arrange them with certainty when misplaced.

No. 4 has the evident tinge which workmen call pale straw colour. It was taken out at 460°, and has the usual temper of penknives, razors, and other fine edge tools. It is much softer than No. 1, as Mr. Stodart assures me, and this difference exhibits a valuable proof of the advantages of this method of tempering.

Nos. 5, 6, 7 and 8, exhibit successive deeper shades of colour, having been respectively taken out at the temperatures 470°, 480°, 490,° and 500°. The last is of a bright brownish metallic yellow, very slightly inclining to purple.

No. 9 obtained an uniform deep blue at the temperature of 580°. The intermediate shades produced on steel by heats between 500° and 580° are yellow, brown, red, and purple, which are exhibited irregularly on different parts of the surface. As I had before seen this irregularity, particularly on the surface of a razor of Wootz, and had found in my own experience, that the colours on different kinds of steel do not correspond with like degrees of temper, and probably of temperature in their production, I was desirous that some experiments might be made upon it by the same skilful artist. Four beautifully polished blades were therefore exposed to heat on the fusible metal. The first was taken up when it had acquired the fine yellow, or uniform deep straw colour. The second remained on the mixture till the part nearest the stem had become purpleish, at which period a number of small round spots of a purpleish colour appeared in the clear yellow of the blade. The third was left till the thicker parts of the blade were of a deep ruddy purple, but the concave face still continued yellow. This also acquired spots like the other, and a slight cloudiness. These three blades were of cast steel; the fourth, which was made out of a piece called Styrian steel, was left upon the mixture till the red tinge had pervaded almost the whole of its concave face. Two or three spots appeared upon this blade, but the greater part of its surface was variegated with blue clouds, disposed in such a manner as to produce those waving lines which in Damascus steel are called the water. Two results are more immediately suggested by these facts; first, that the irregular production of deep colour

upon the surface of brightened steel, may serve to indicate the want of uniformity in its composition, as well as the method by an acid which has before been explained in this work; and second, that the deep colour being observed to come on first at the thickest parts, Mr. Stodart was disposed to think, that its more speedy appearance was owing to those parts not having been hardened. But upon trial with a plate of steel made quite hard at one end, and left soft at the other, I found that heat applied in the middle produced the regular changes at both ends precisely in the same manner. I suppose, therefore, that the thicker parts sinking deeper into the hot metal, experienced a stronger re-action and better contact, which may have accelerated the communication of heat. It may be here noticed, that we found upon repeating the experiment of applying nitrous acid to bright steel, which was hardened in part only, the black tinge appeared more speedily and strongly upon the hard parts, than the rest of the surface: a remarkable event, for the explanation of which I have no theory to offer.

Let us now suppose our cutting instrument to be forged, hardened, and let down or tempered. It remains to be ground, polished, and set. The grinding of fine cutlery is performed upon a grindstone of a fine close grit, called a Bilson grindstone, and sold at the tool shops in London at a moderate price. The cutlers use water, and do not seem to know any thing of the method by tallow. The face of the work is rendered finer by subsequent grinding upon mahogany cylinders, with emery of different fineness, or upon cylinders faced with hard pewter, called laps, which are preferable to those with a wooden face. The last polish is given upon a cylinder faced with buff leather, to which crocus, or the red oxide of iron is applied with water. This last operation is attended with considerable danger of heating the work, and almost instant-

ly reducing its temper along the thin edge, which at the same time acquires the colours of oxidation.

The setting now remains to be performed, which is a work of much delicacy and skill: so much so indeed, that Mr. Stodart assures me, he cannot produce the most exquisite and perfect edge if interrupted by conversation, or even by noises in the street. The tool is first whetted upon a hone with oil, by rubbing it backwards and forwards. In all the processes of grinding or wearing down the edge, but more especially in the setting, the artist appears to prefer that stroke which leads the edge according to the action of cutting, instead of making the back run first along the stone. This proceeding is very judicious; for if there be any lump or particle of stone, or other substance lying upon the face of the grinder, and the back of the tool be first run over it, it will proceed beneath the edge, and lift it up, at the same time producing a notch. But on the other hand, if the edge be made to move foremost, and meet such a particle, it will slide beneath it and suffer no injury. Another condition in whetting is, that the hand should not bear heavy: because it is evident, that the same stone must produce a more uniform edge if the steel be worn away by many, than by few strokes. It is also of essential importance, that the hone itself should be of a fine texture, or that its siliceous particles should be very minute. Mr. Stodart informs me that there are no certain criterions by which an excellent hone can be distinguished from one of ordinary value, excepting those derived from the actual use of both: that the Turkey stone cuts fast, but is never found with a very fine grit: that the yellow hone is most generally useful, and that any stone of this kind requires to be soaked in oil, and kept wet with that fluid, or otherwise its effects will be the same as that of a coarser stone under the better treatment: and lastly, that there is a green hone found in

the old pavement of the streets of London, which is the best material yet known for finishing a fine edge.

The grindstone leaves a ragged edge, which it is the first effect of whetting to reduce so thin, that it may be bended backwards and forwards. This flexible part is called the wire, and if the whetting were to be continued too long, it would break off in pieces without regularity, leaving a finer, though still very imperfect edge, and tending to produce accidents while lying on the face of the stone. The wire is taken off by raising the face of the knife to an angle of abut 50 degrees with the surface of the stone, and giving a light stroke edge foremost alternately towards each end of the stone. These strokes produce an edge, the faces of which are inclined to each other in an angle of about 100 degrees, and to which the wire is so slightly adherent, that it may often be taken away entire, and is easily removed, by lightly drawing the edge along the finger nail. The edge thus cleared is generally very even: but it is too thick, and must again be reduced by whetting. A finer wire is by this means produced, which will require to be again taken off, if for want of judgment, or delicacy of hand, the artist should have carried it too far. But we will suppose the obtuse edge to be very even, and the second wire to be scarcely perceptible. In this case the last edge will be very acute, but neither so even nor so strong as to be durably useful.

The finish is given by two or more alternate light strokes with the edge slanting foremost, and the blade of the knife raised, so that its plane forms an angle of about 28 degrees with the face of the stone. This is the angle which by careful observation and measurement, I find Mr. Stodart habitually uses for the finest surgeons instruments, and which he considers as the best for razors, and other keen cutting tools. The angle of edge is therefore about 56 degrees.

The excellence and uniformity of a fine edge may be ascertained, by its mode of operation when lightly drawn along the surface of the skin, or leather, or any organized soft substance. Lancets are tried by suffering the point to drop gently through a piece of thin soft leather. If the edge be exquisite, it will not only pass with facility, but there will not be the least noise produced, any more than if it had dropped into water. This kind of edge cannot be produced, but by performing the last two or more strokes on the green hone.

The operation of strapping is similar to that of grinding or whetting, and is performed by means of the angular particles of fine crocus, or other material bedded in the face of the strap. It requires less skill than the operation of setting, and is very apt, from the elasticity of the strap to enlarge the angle of the edge, or round it too much.

Letter on the Properties of tempered Steel.

To Mr. NICHOLSON.

SIR,

In one of your Journals, I do not recollect which, you signified your intention of giving in a future number, some ideas upon certain singular properties of tempered steel. A number of unexplained facts have for some time been known to the workers of steel-plate. As I am concerned in a manufactory of the kind, and in the daily habit of witnessing those curious and anomalous appearances, I thought you might in some measure profit by the following description of the changes which take place in the various processes of hardening, tempering, hammering, burnishing, &c.

I took a steel-plate 30 inches long, 12 broad, and about ,04 thick ; I hardened it in a composition of oil and tallow, and afterwards tempered it down to a spring temper ; it was now so elastic as to recover its position after being

bended; by hammering it to set it straight, it lost a part of its elasticity; after being ground in the same manner as a saw, the elasticity, became still less, having nearly returned to the same state as before hardened; it was then very uniformly heated till it became blue, it now recovered the whole of its elasticity; after being glazed bright upon a glazier coated with emery, the elasticity was found to be impaired, but in a less degree than when it was ground; the same effect was also produced by rubbing with emery or sand-paper, and also by burnishing; invariably the elasticity was recovered by bluing, and hence this is always the last operation in the manufactory of elastic steel-plate. Should you at some future opportunity favour the public with your opinion on this subject, and these hints have in the least assisted your inquiry, it will be the utmost wish of

Your humble and obedient servant,

Sheffield, T. B.

June 18, 1806.

On the Choice of Steel, and the Methods of hardening and tempering it.

For ordinary purposes, the method noticed by Mr. Collier in his paper on iron and steel, will answer very well, both for hardening and tempering; but in many cases it is necessary that the steel should be of the best quality, and be both hardened and tempered in such a manner as to preserve the greatest hardness possible without brittleness; and steel is of more or less value in proportion as it possesses this property in a greater or less degree.

Steel, when soft, can be wrought into almost any form as well as iron, welding excepted, of which the better sorts, particularly cast steel, are incapable. It can be forged, filed, turned in a lathe, drawn into wire, rolled into large plates, &c. &c. and, when by these means brought into

the desired form, it can then be made so hard as to be capable of cutting the hardest substances (the precious stones excepted), while at the same time it is almost proof against being itself worn by friction: but in this state it is brittle, like all other hard substances, and for many purposes must have this brittleness lessened, and this is what is termed by workmen, tempering, and consists in giving it certain degrees of heat according to the temper desired, which may be produced in any degree until the whole effect of hardening is destroyed, and the steel is reduced to its soft state. On each of these operations I shall offer a few remarks, proved by long experience; and, first, on the choice of steel for such purposes as require the best that can be procured for making cutting instruments, such as gravers, punches, turning tools, chisels, &c. &c. to be employed in turning or cutting tempered steel, and substances that are too hard to be cut by tools made of ordinary steel: for these purposes cast steel is undoubtedly the best; but even this sort differs in quality.

The general mode of choosing such as is most suitable for the above purposes is to break a bar, and observe its fracture, and to select the closest grained; but this mode is not always certain, owing to the difference made in the fracture by the steel being hammered under a greater or less degree of heat, steel being much improved by being hammered under a low heat, and even when cold; and when overheated, being quite spoiled for the above purpose. It is owing to this circumstance that the best sorts of cast steel are incapable of being welded as above mentioned. Another method is, to harden with as low a heat as possible a piece of steel, and then to break it, and observe its fracture: but this is not wholly to be depended upon; for some steel breaks with a very close grain, and yet is not of a good quality. But the surest method is to

have one end of a bar drawn out into a small rod under a low heat, an obscure red for instance, or but little above; then heat it as before, and suddenly plunge it into pure cold water: if it proves hard, and requires a great force to break it, it is good, let its fracture be what it may: and I have always found that the specimens that hardened with the lowest heat, and when in that state required the greatest force to break them, proved the best steel. Having thus selected steel fit for the required use, and, with the precautions already noticed, given it the proper form, it may be hardened; but the same method will not answer for all purposes. Some pieces, from their size and figure, are very difficult to be hardened; if they are large, they heat the water in immediate contact with them, and the heat is communicated to the rest of the water, so fast that it prevents the pieces from being cooled quick enough to produce the desired effect: this is in part prevented by continually moving the piece about in the water; but when too large to be hardened by this method, a stream of water must be employed; and for such pieces as the face of large anvils, a birch broom is used with advantage to break the bubbles that are formed by the continual disengagement of air, and which, if not swept away, would prevent that intimate contact and uniform succession of the stream necessary to produce the degree of hardness required. Other articles from their length, are difficult, and almost impossible to be made hard without bending, or otherwise altering their figure: this circumstance occasions a great deal of trouble; and many a piece of work is spoiled, after a good deal of labour has been bestowed upon it. The method that has succeeded best with me is, either to inclose the piece or pieces intended to be hardened in an iron case or box, open at one end (for the more ready dropping the pieces into the water), and giving it a slow yet regular heat; then to take the case out

of the fire, and drop the pieces into the water in such manner as will allow them to come as little as possible in contact with the air. This method answers two good purposes at once, causing the heat to be more equally applied, and preventing the contact of the air, and of course any scaling; and when the work has been polished and well defended from the air, it comes out nearly as clean as it was before. When the greatest possible hardness is required, it may be obtained by using quicksilver instead of water; but this can only be employed for small articles. For some purposes steel is required to have a superior degree of hardness given to its surface, such as in the case of files, &c. This is obtained by using a coarse powder made of leather slightly burned, hair or horn, either in raspings or in powder; this is mixed with a little common salt, and the files when just red hot, are thrust into a heap of this powder, some of which adhering to their surface is carried into the fire with them, and gives them a case hardening: the salt fluxes upon their surface, and defends them from the air while passing from the fire into the trough of water, into which they are plunged to harden. The workmen say, the longer this water is used for this purpose the better.

We are now come to the last process called tempering, for one method of which see Mr. Collier's paper; but that method cannot be conveniently applied in all cases, and has several disadvantages, some of which I shall mention. First, each piece must be made bright that the change of colour may be better seen, and must be heated singly or nearly so; and pieces of irregular figure cannot be made to receive an equal degree of heat in all their parts, so that some will be softer than others. These circumstances would retard the manufactory of many articles very much, and prevent their being afforded at the present prices, such as the springs of gun locks, door

locks, various articles in clock and watch work, &c. &c. The necessity of making them bright enough to mark the change of colour is obviated by smearing them with oil or tallow, which helps to apply the heat more uniformly, and marks the temper as well as by observing the colour, or nearly so; or by putting the things to be tempered into a proper vessel, and adding so much oil or tallow as will cover them, and then holding them over the fire or the flame of a lamp until a sufficient heat is given. By this means the most irregular pieces may be uniformly heated, and great numbers may be done at one time, and with great certainty: thus are clock and watch pinions, watch verges, balances, &c. tempered; sometimes many dozens at once; and no more time is necessary for the whole than would be for one single article. The requisite temper may be known by the following circumstances: When such a heat is given that the tallow is first observed to smoke, it indicates the same temper as that called a straw colour: this will reduce the hardness but little; but if the heat is continued until the smoke becomes more abundant, and of a darker colour, it will be equal to a brown, and indicates a temper that may be wrought—that is, which may be turned or filed, but with difficulty, and only when a mild sort of steel is employed. If the tallow be heated so as to yield a black smoke, and still more abundant, this will denote a purple temper; and if the steel is good, it will now work more pleasantly, though still hard enough to wear well in machinery. The next degree may be known by the tallow taking fire if a lighted body is presented to it, but yet not so hot as to continue to burn when the light is withdrawn; this would equal a full blue colour. Increase the heat till the tallow continue to burn, being once lighted, and this will denote a pale blue: and if the whole of the tallow be allowed to burn away, or to burn dry, as the workmen call

it, it gives what clock-makers mostly use for their work. Farther tallow is useless; a small degree of heat more would just be seen in a dark place, or the lowest degree of a red heat: such is the temper given to the springs for coaches, &c.. Thus I have given a reason why oil or tallow is made use of, and given you the parallel degrees of temper which by a dry heat are observed by the change of colour only. The method of hardening in quicksilver is of great use where a superior degree of hardness is required; and good steel so hardened, when the precautions before mentioned are duly attended to, will cut glass like a diamond, and turn or cut other steel at so high a temper as to differ but little from quite hard.—Perhaps at a future time I may give you a method by which this hardest of steel may also be worked with considerable ease, and the cases in which I have applied it to advantage.

As steel is always found more compact and strong bodied when hardened with a low heat, and as that effect is best obtained the colder the water is which is employed hardening it, provided the water is clean, (a circumstance which should always be attended to,)—it appeared probable, that if water was cooled down to the freezing point, or even lower, which it may be, and retain its fluidity by being kept in a state of perfect rest, the effect might be heightened. I caused a large heap of snow to be collected together at a time when the thermometer stood at 22° of Fahrenheit, and making a deep hollow in the middle, I set a glass of clean water in the bottom of the hollow, and covered the whole with a board to prevent the air from disturbing or causing any motion in the water. I heated some pieces of steel in the breech end of a gun barrel to a low red heat; and by means of an assistant to take off the board at the instant I arrived with the heated barrel and its contents, I quickly dropped the pieces into the water; which having stood all the preceding night in the

situation above described, must, though still fluid, have been cooled down to the temperature of the surrounding snow, which was still found to be 22°. Upon taking them out, I found the pieces hard but brittle, having the appearance of steel that had been overheated.

Being disappointed in what I had expected, I intended to repeat the experiment with a still lower heat; but an alteration in the state of the air prevented me from prosecuting the experiment at that time, and having since succeeded in making use of quicksilver instead of water, I have never resumed the experiment. As methods are now well known by which water may be cooled below the freezing point, even by the fire side, and at an easy expense, some one who has time may perhaps think the experiment worth repeating: it might cast some light upon the subject of hardening steel, and lead to some useful results.

The dish I employ for tempering is made of plate-iron, with an edge turned up on every side a sufficient height to hold tallow or oil enough to cover the pieces to be tempered. The corners are nipped together, and then folded up against the sides; by which means they are prevented from letting out the oil.

Another turned up on three sides only, is used to lay pieces intended to be hardened: a cover is of advantage where the pieces are intended to come out clean and bright, as it more perfectly defends them from the air, and of course prevents oxidation from taking place. By this instrument, the work, though ever so small or slender, may be brought out of the fire and dropped into the water with very little loss of heat. It ought to be made of stronger plate-iron than is necessary for the other pan, and the corners cut out so that the sides may bend up more square. They need not be folded as in the other, not

being intended to hold any liquid substance. Such articles as small drills, pendulum and other small springs, need not be dropped into water, but only made to pass through the air by tossing them out and letting them fall to the ground, which will make them hard enough for most purposes.

Small drills may be hardened by holding their points in the flame of a candle, and, when sufficiently hot, suddenly plucking them out: the air will harden them; and they may then be tempered, by taking a little of the tallow upon their point, and then passing them through the flame at about half an inch above the point, and holding them there till the tallow begins to smoke. This method, known to all watchmakers, may be of use to other artists, and therefore not unworthy of the notice I have taken of it. S. Varley. 2 Phil. Mag.

Properties of blued Steel not generally known.

IN making springs of steel the metal is drawn or hammered out and fashioned to the desired figure. It is then hardened by ignition to a low red heat and plunging it in water, which renders it quite brittle. And lastly, it is tempered either by blazing or bluing. The operation of blazing, consists in smearing the article with oil or fat, and then heating it till thick vapours are emitted and burn off with a blaze. I suppose this temperature to be nearly the same as that of boiling mercury, which is generally reckoned to be at the 600 of Fahrenheit, though for reasons I shall in future mention, I think this point requires to be examined. The operation of bluing consists in first brightening the surface of the steel, and then exposing it to the regulated heat of a plate of metal or a charcoal fire, or the flame of a lamp until the surface acquires a blue colour by oxidation. The remarkable facts which I have here to present to the notice of philosophers, are, that Mr.

Stodart assures me that he has found the spring or elasticity of the steel to be greatly impaired by taking off the blue with sand paper or otherwise; and, what is still more striking, that it may be restored again by the bluing process without any previous hardening or other additional treatment.

Mr. Hardy, who is meritoriously known as a skilful artist, assured me some time ago that the saw-makers first harden their plates in the usual manner, in which state they are more or less contorted or warped, and are brittle;—that they then blaze them; which process deprives them of all springiness, so that they may be bended and hammered quite flat, which is a delicate part of the art of saw making;—and that they blue them on an hot iron which renders them stiff and springy without altering the flatness of their surface. Mr. H. finds that soft, unhardened steel, may be rendered more elastic by bluing, and that hard steel is more expansible by heat than soft.

It is very difficult to reason or even to conjecture upon these facts. They certainly deserve to be verified by a direct process of examination. 12 Nich. Jour. 63.

Observations and experiments on steel, resembling that of Damascus; with an easy test for determining the uniform quality of steel before it is employed in works of delicacy or expence.

In the infancy of society the hardest bodies, such as stones, and certain kinds of wood, were selected and used for cutting instruments, and still are applied to that purpose in several parts of the world. These materials were succeeded by copper, hardened by a mixture of tin, of which numerous weapons yet remain in the cabinets of the curious. And lastly, steel, whether obtained directly from the ore, or by cementation of malleable iron, has deservedly taken place of every other article, on ac-

count of the united qualities of tenacity and hardness. When the sword was the chief weapon of war, it must have been an object of great interest and demand to give to its blade a durable keen edge, and a degree of firmness or strength, which, without rendering it unwieldy, should ensure the warrior against exposure to the fatal accident of its breaking in the act of combat. The sabres of Damascus have been famous for ages, and still bear a great price in the East; but we have no decided account of the manner in which this steel is manufactured or made up. Some years ago I was favoured with the possession of a true blade of this kind for a few days, which, if my recollection be accurate, had cost the possessor twelve guineas at Constantinople. I know the sum was not less than this. As I was not permitted to make any experiments upon it, I could only ground my process upon reasoning from its external appearance and obvious qualities.

It had a dull grey or bluish appearance, was scarcely harder than common steel from the forge, was not easily bended, and when bended had no spring to recover its figure. Its back was smooth, as were also two narrow sloped surfaces which formed its edge under an angle of about 40 degrees; but its flat sides were every where covered with minute waving lines in masses in all directions, not crossing each other, and, for the most part, running in the direction of its length. The lines were in general as fine as harpsichord wire, not extremely well defined nor continued; and their distinction from each other was effected by no perceptible indentation of the surface, but rather by the succession of parts differing in the degree of polish or brightness. No one, upon inspection of this surface, would for a moment have imagined or allowed that it could have been done by engraving or etching, as the false blades are damasked. I was informed that if any part of this blade were made smooth by grinding or whet-

ting, the wavy appearance, called the water, could be again produced by means of lemon juice; and that its excellencies were, that it could be depended upon not to break, and that it would cut deeper into a soft substance, such as a pack of wool, or into flesh, than any other kind of blade.

From these circumstances, as well as from the price, I was induced to think that the blade was composed of steel and iron, and that the process of forging was such as greatly to enhance the cost, by the labour and management it might require. For if we suppose the pieces to be united together at the welding heat, and then forged or drawn out, it is certain that no small degree of skill and care would be required to render all the parts sound, and at the same time preserve the steel and iron in possession of their characteristic properties. Too great a heat would probably render the whole mass more uniform than is consistent with the subsequent production of the water or wavy appearance. In my attempt to imitate this steel, I endeavoured to substitute a mechanical contrivance in the place of this supposed careful forging.

I caused a cylindrical hole of about one inch in diameter to be bored through a piece of cast iron, the lower part of which could be so placed upon an anvil as to close one end of the hole. A forged iron plug was made nearly to fit the cylindrical hole, but considerably longer. Equal weights of German steel and Swedish iron, both in filings, were then well mixed with oil, and wrapped in a paper, which had before been rolled upon the plug, and consequently fitted the cylinder. The ends of the paper were neatly folded; and the whole mass being then put into the cast-iron cylinder placed upon the anvil, a few blows were given by driving the plug into the hole with a heavy hammer. By this means the mass of filings, when thrust out of the cylinder, was compact and manageable.

It was then placed in a charcoal fire, and urged to a welding heat by the double bellows. Thence it was taken with the tongs; again hastily put into the cylinder, and hammered by means of the plug and the heavy hammer. When it was taken out, the whole was found to be consolidated; but upon forging it into a plate, a considerable portion flew off in a crumbly form. The plate, however, was filed up, smoothed, and examined.

Its colour presented nothing remarkable. When weak nitrous acid was poured upon it, it became mottled in consequence of the numerous small black spots which appeared upon the particles of steel, while those of iron remained clean. On the nitrous acid being washed off, the surface appeared wavy like the Damascus steel, but scarcely at all fibrous; doubtless because the solid had not been drawn out by forging. An attempt was made to harden it by ignition and cooling in water; but it still remained soft enough to be cut with the graving tool, the point of which did not indicate any difference in that respect between the parts of iron and of steel, though it is very probable such a difference did really exist.

I infer, therefore, that the Damascus steel is in fact a mechanical mixture of steel and iron; that it is incapable of any considerable degree of hardness, and consequently is in no danger of breaking from its brittleness; that its tenacity is ensured not only from the admixture of iron, but likewise from the facility with which its soundness may be ascertained throughout, by the same process which exhibits the water or fibrous appearance: and, lastly, that the edge of a weapon formed of this material must be rough, on account of the different resistance which the two substances afford to the grindstone, in consequence of which it will operate as a saw, and more readily cut through yielding substances

than such cutting tools as are formed of a more uniform substance.

This experimental enquiry directed my attention to a method of ascertaining the uniformity of texture in iron or steel, which perhaps may have been noticed by others, but is certainly unknown in most manufactories, though I have found it of great utility. If a weak acid, for example the nitrous, which I have usually taken in a very diluted state, be applied to the face of iron or steel previously cleaned with the file, or with emery paper, the parts which contain the greatest portion of carburet of iron (or plumbago) immediately shew themselves by their dark colour. It very frequently happens that articles of considerable value, intended to be fabricated in iron or steel, are not known to be defective until much expence has been laid out in manufacturing them. A piece of iron, which has a vein of steel running through it, as is too often the case, will require at least three times the labour and care to turn it in the lathe, which would have been demanded by a piece of greater uniformity. Steel which abounds with spots, or veins, or specks called pins, may be fashioned completely, and will not shew its defects, until the final operation when an attempt is made to polish it. Other articles, such as measuring screws, blades of sheers, fine circular cutters, &c. either bend in the hardening, from the difference of expansion, or resist the tool when wrought in the tempered state, or exhibit other incurable defects when they come to be tried; which the test by nitrous acid would have indicated before any expense had been incurred. In these, and in numberless other instances, it would have been incomparably more advantageous to have rejected the material upon the first trial, rather than have proceeded to the very expensive process of manufacturing the article and then finding it of no value. By this simple expedient I

have found bars of steel as full of veins and irregularities as wood, and have been enabled to select the best and most uniform pieces for works of the greatest delicacy; whereas, before I thought of this mode of trial, I have very often had the mortification to fail in the last stage of experimental processes, upon which much cost and labour had been bestowed.

Account of an Experiment to imitate the Damascus Sword Blades, in a letter from Mr. JAMES STODART, to Mr. NICHOLSON.

DEAR SIR,

Having lately had an opportunity of examining some sword blades, which appeared to be defective, I was induced to make the following experiment. The subject is surely of some importance, and perhaps never more so than at the present moment. We hear of swords having broken in battle, and we can hardly imagine a more distressing circumstance. Those which I have seen are certainly in no danger of failing in that way, for on the contrary they are evidently too soft, and consequently cannot form a good cutting edge. I am not acquainted with the process used in making sword blades, but am inclined to suspect that the price allowed, is not equal to the labour necessary to form a good instrument. The following method, which I believe to be nearly the same as that practised at Damascus, but which I suspect would be too difficult and expensive for general application, may perhaps lead to some more simple method of accomplishing the desired purpose. I took six small bars of good malleable iron, and the same number of sheer steel, and laid them one on another alternately, as if forming a galvanic pile; I then with the assistance of an expert workman, committed them to a clean forge fire, and with care we succeeded in welding them into a solid lump. This was

forged into a stout flat plate, which being heated to whiteness, was by means of strong tongs twisted spirally until it formed a cylindrical tube. In this twisted state it was heated, hammered flat, and again welded, and after being forged into a convenient form and substance, was doubled throughout its whole length, somewhat in the manner of the back of a saw. A slip of good steel was inserted, and another welding heat taken, which consolidated the whole mass. I need not say this slip of steel was intended for our edge. The remaining part of the process was simple; it consisted only in forging it into the shape of the blade we wanted; which on examination proved perfectly sound in every part. Being eager to witness some proofs of excellence and beauty which my expectation had anticipated, I too hastily and without due consideration proceeded to harden it by heating and quenching in water; and had the misfortune to see it cracking in seven or eight different places. I have no doubt this was occasioned by the unequal expansion and subsequent contraction of the different parts of the mass. In my next trial I shall guard against this accident. Enough however remained sound to prove it both good and beautiful; the edge bears the severest trials at the same time that the whole blade has sufficient tenacity. I have polished a part of it, and by applying a weak acid, produced an appearance, which though by no means equal to the beauty of what is called the Damascus water, leaves me little reason to doubt of accomplishing that appearance in my next trial. My intention is to multiply my pieces of metal, to repeat the process of twisting, and certainly not again to quench in water. I shall take the liberty to transmit to you an exact account of my next experiment, and if successful, to accompany it with a sample of the metal formed into a blade of some kind or another. I am with much respect,

Your obedient servant,

J. STODART.

P. S. Why is the appearance produced on Damascus steel by the application of an acid called the water? Is it not different degrees of oxidation?* and what is the acid best fitted to produce this appearance. I had a paper given me some ten years ago on this subject, by a gentleman whose name I do not know. Unfortunately I have mislaid it.

In addition to what you have published on the subject in your valuable Journal, pray furnish us with any other facts that may have come to your knowledge since that period. The subject appears to me to be worthy of philosophical research, and perhaps of national encouragement.

Welding of Cast-Steel. By Sir THOMAS FRANKLAND, *Bart.*

The uniting of steel to iron by welding is a well known practice; in some cases for the purpose of saving steel; in others, to render work less liable to break, by giving the steel a back or support of a tougher material.

Ever since the invention of cast-steel (or bar steel refined by fusion) it has generally been supposed impossible to weld it either to common steel or iron; and naturally— for the description in Watson's Chemical Essays (vol. iv. p. 148) is just, that in a welding heat it " runs away under the hammer like sand." How far the Sheffield artists, who stamp much low-priced work with the title of cast-steel, practise the welding it, I am ignorant; but though I have enquired of many smiths and cutlers in different parts of the kingdom, I have not yet found the workman

* I have always supposed steel to be less readily soluble than pure iron; and that the carbon which is seen on the face of the former during the process of damasking, defends it from the acid, while the fibres of iron are etched by corrosion so as to exhibit the peculiar waving lines of this operation. N.

who professed himself able to accomplish it. If therefore I should describe a simple process for the purpose, I may be of use to the very many who are incredulous on the subject. If any one has made the discovery on principle, he has reasoned thus: Cast-steel in a welding heat is too soft to bear being hammered; but is there no lower degree of heat in which it may be soft enough to unite with iron, yet without hazard of running under the hammer? A few experiments decided the question; for the fact is, that cast-steel in a white heat, and iron in a welding heat, unite completely.

It must not be denied that considerable nicety is required in giving a proper heat to the steel; for, on applying it to the iron, it receives an increase of heat, and will sometimes run on that increase, though it would have borne the hammer in that state in which it was taken from the fire.

I need scarcely observe, that when this process is intended, the steel and iron must be heated separately, and the union of the parts proposed to be joined, effected at a single heat. In case of a considerable length of work being required, a suitable thickness must be united, and afterwards drawn out, as is practised in forging reap-hooks, &c.

The steels on which my experiments have been made, are Walker's of Rotherham, and Huntsman's, between which I discover no difference; and though there may be some trifling variation in the flux used for melting, they are probably the same in essentials.*

* Mr. Pettibone of Philadelphia has succeeded in this process.

Of the CHEMICAL MANUFACTURES DEPENDANT UPON *Iron, viz.* GREEN COPPERAS: INK: PRUSSIAN BLUE: COLCOTHAR, CROCUS MARTIS.

COPPERAS.

Green copperas: sulphat of iron; is procured three ways, viz. from pyrites: from the precipitation of copper-water: from solution of iron directly in sulphuric acid.

First method. Pyrites, or sulphuretted iron, is found frequently in great abundance in strata of argillaceous shist; in England particularly, in the stratum superincumbent upon coal.

" The sulphuric acid dissolves iron, and forms the well known salt *Sulphat of iron; Green vitriol; Green copperas;* or *Sal martis.* The greater quantity of this salt which is used in manufactures of various kinds, particularly in dying black, is not prepared from the direct combination of its ingredients, but from various kinds of native sulphats of iron, or pyrites, after they have undergone spontaneous oxygenation by long exposure to air. Green vitriol is prepared in many counties in England; the first manufacture of the kind was undertaken in the reign of queen Elizabeth, at Deptford, where it is still carried on. It is likewise made largely in Northumberland and Durham. The method of manufacture is simple, and scarcely differs now from what it was more than a century ago as described by Colwall."

The following is the process actually in use.

" The usual mode of manufacturing copperas on the " rivers Tyre and Wear, is by exposing iron pyrites (there " called *brasses*) which are found in the collieries, to the " influence of the atmosphere. For this purpose a situa- " tion is chosen inclining towards the river, of a natural " strong clay. After the soil is taken off, gutters are cut " in different directions, and wells of about 5 or six feet

" deep, and two or three in diameter, are sunk where the " gutters terminate. Upon this surface the *brasses* are " laid to the thickness of 4 or 5 feet. The vitriolization " shews itself in a white efflorescence, which is washed " off by the rain into the gutters and conveyed by " pipes from the wells to a reservoir, from which there " is a pipe of communication to the boiler. This is " a leaden vessel generally about 7 feet deep, 12 to " fourteen long, and 6 or 7 wide, where the liquor is eva- " porated for 6 days, during which time a quantity of old " iron is added to it, as much as it will dissolve. It is then " run into a crystallizing vessel, and remains there for " five weeks, at the end of which time the mother liquor " is run into a reservoir, and pumped back into the boil- " er, and the crystals are removed, and after being well " drained are packed in hogsheads for sale. A single " boiling from a boiler of the above dimensions yields " from 5 to 8 tons of copperas, according to the strength " of the liquor."

Vitriol is made near Haguenau on the Rhine nearly in the same manner, according to the description given by Cavillier. The pyrites is disposed on an inclined soil in beds about two feet thick, beneath which are gutters going to a common reservoir. The vitriolization of pyrites is always seen by whitish efflorescences tasting strongly of vitriol, at the same time that the surface of the pyrites cracks in every direction. When the season is dry it is occasionally watered to carry off the vitriol already formed, and to promote a fresh vitriolization in the remaining ore. The heaps are found to be exhausted when these saline efflorescences are but scanty, and when the lump when broken appears changed throughout into the *liver pyrites*.

The vitriolic liquor is evaporated as usual in lead boilers, but it does not appear that old iron is regularly added

to saturate the liquor as in England, but only occasionally when it appears too acid. Some of the mother liquor of the former operation is always added.

The evaporated liquor before it passes into the crystallizing pools is sent to another bason, where it remains for twenty-four hours to deposit a large quantity of ochre. The crystallizing pools are made of fir planks surrounded with beaten clay. It requires ten days for the solution to deposit all its crystals, part of which is collected on sticks put into the vessel, but the purest vitriol is deposited the last. The liquor that remains after the deposition of the crystals (or the *mother-water* as such liquors are always termed) is reserved, and a portion is always added to the boiler in the next evaporation.

The vitriolization of the common pyrites used in these manufactures is a work of considerable time, more or less according to circumstances, but is generally several months before a bed is entirely exhausted. Vitriol is however also made in several places from *vitriolic peat*, and in this the process is much shorter. A large manufactory of vitriol from this source is carried on near Beauvais in France, thus described by M. Brisson.

The peat in the neighbourhood is of two kinds, the common combustible peat and the vitriolic. The former is, as in other countries, light, spongy, and full of visible remains of leaves, stalks, and vegetable fibres. The vitriolic on the other hand is easily distinguished by being heavier, harsher, and crumbly. The waters that run from it also deposit much ochre which readily detects the situation. The vitriolic peat is not found uniformly in any relative situation with the other species, but at different depths from the surface to about ten feet.

This peat is hardly exposed to the air before it opens of itself and becomes very dry and harsh, and soon heats even in small masses. To render the vitriolization more uni-

form and prevent the too drying effect of the sun, the peat is laid in heaps, only three or four inches in thickness under sheds thatched with straw, where they remain for a few days, after which they are ready for lixivation. This is done by throwing the peat into large vats of masonry and covering it with rain water, which flows through the heaps and is collected for the purpose, and also with some of the mother water of the former crystallization. It is then evaporated and crystallized in the method already described.

In some places the pyrites requires roasting before it can be decomposed by the action of the air. Thus at Geyer in Saxony, the pyrites, after being exposed for some time to the air, is soaked in water for twelve hours, then roasted as in the ordinary method of roasting ores, in a large bed upon faggots, on which about seventy or eighty quintals at a time are heated red-hot, and in this state plunged again into water. This is repeated six times successively with the same pyrites, by which the water becomes strongly impregnated with vitriol and is afterwards evaporated and crystallized as usual.

A quantity of heat is always generated during the process of vitriolization, both in the first combination of iron with sulphur and the subsequent oxygenation of the sulphur, and consequent conversion into sulphuric acid, which enables it to dissolve the iron and form the sulphat required.

The degree of the heat produced, and the quantity of moisture which the pyrites receives (by rain or other sources) are the circumstances that principally regulate the production of vitriol, both as to quantity and time of its production. Too much heat actually kindles the mass; the remaining sulphur takes fire, and an immense quantity of sulphureous acid vapour is given off to a great distance around. Where this takes place, little or no vitriol

is produced, for most of the sulphur and acid already formed is dissipated and also the iron becomes too much oxydated to yield the crystallizable salt. Hence it is dangerous and prejudicial to make too large heaps of pyrites or to put it up into stacks however preserved from the weather. Some moisture is also necessary to vitriolization, but too much of it keeps the pyrites too cold, and the process is languid. The iron added during the boiling is certainly useful, both as saturating the acid and encreaing thereby the yield of the salt, and also as precipitating by its superior affinity any copper which may arise from the admixture of copper pyrites, and also undergo vitriolization. In some manufactures however the admixture of a small portion of sulphat of copper is even an advantage, as in the dying of hats. (Aikin's Dict. I. 614)

Second method. In copper works, the sulphuretted ore of copper is roasted in ovens to drive off part of the sulphur. The ore is then washed. But as in the process of desulphuration, much of the sulphur is acidified by the oxygen of the air that supports the combustion, a sulphat of copper, or blue vitriol, blue copperas, is produced. When the ore is washed in water, that water dissolves the blue vitriol, from which the copper is precipitated by immersing bars and plates of iron in the solution. The copper thus precipitated is nearly in a metallic state; and when no more copper falls down, the iron is taken out, the precipitate collected for fusion, and the liquor which now contains sulphat of iron is evaporated to obtain that salt, which crystallizes in the usual way.

Third method. Oil of vitriol (concentrated sulphuric acid) is mixed with six times its bulk of water. Refuse iron is immersed in it till the liquor is saturated, and will take up no more iron. The clear liquor is gently evaporated and left to crystallize. One hundred parts by

weight of oil of vitriol, will yield 250 parts of chrystallized green copperas.

INK.

This is the gallat of iron, which turns black by exposure to oxygen, and then precipitates. The precipitate for the purpose of writing is suspended in water by means of mucilage of gum arabic. White sugar gives a gloss to the ink, but renders it more slow in drying. Hence it is an useful addition to copying ink.

I do not know a better composition for common ink than the following.

Logwood rasped or finely chipped, 1 ounce

Nutgalls in powder, 3 ounces

Green copperas calcined to whiteness, 1 ounce and a quarter

Blue copperas, ¼ of an ounce

Gum arabic pounded, 1 ounce and a half

White sugar, ¼ of an ounce

Water one quart; vinegar one pint.

The vinegar and water should be poured hot upon the ingredients in a close vessel. When, cool it should be frequently stirred with a stick, for a fortnight. It may then be strained through a cloth, and put in a bottle.

Mr. Watt's receipt for the ink used for his copying press, and the preparation of the paper, is as follows.

Take a piece, or pieces, of thin paper which contains no size, or glue, or gummy or mucilaginous matter, or which at least does not contain so much size, or other matter, as would make it fit for being written upon. Cut this paper, or papers, to the size and shape of the writing of which a copy is wanting: moisten or wet the said thin paper with water, or other liquor, by means of a spunge or brush, or by dipping, or otherwise. Having moistened or wetted the thin paper, lay it between two thick

unsized spongy papers, or between two cloths, or other substances capable of absorbing the superfluous moisture from the thin paper; when it has been slightly pressed between such thick spongy papers, or other substances, by the hand or otherwise, lay the said thin paper, so moistened and pressed, upon or under the side of the writing which is to be copied, and in such manner that the one side of the said moistened paper shall be in contact all over the side of the said writing, so intended to be copied; and that, to the other side of the said moistened thin paper, there shall be applied a piece of clean writing-paper, or cloth, or other smooth uniform substance. Lay the said writing intended to be copied, with the thin moistened paper intended to receive the copy, (placed respectively as above directed,) upon the board of a common rolling-press, or of that of which a description and drawing are hereunder written and drawn, and press them once, or oftener, through the rolls of the said press, in the same manner as is used in printing by copper-plates; or instead of using the said or any rolling-press, squeeze the said papers, placed respectively in the manner above described, in a screw press; or subject them to any other pressure sufficient for the purpose: by means of which pressure, in whatever manner applied, part of the ink of the writing intended to be copied shall press from the said writing in to, upon, and through, the said thin moistened paper, so that a copy of the said writing, more or less faint, according to the quality of the ink and paper employed, shall appear impressed on both sides of the said moistened paper, viz.—Upon one of the sides in the natural or proper order and direction of the lines, as they are in the original writing, and on the other side in the reverse order and direction. But, in order to make the impression or copy of the writing more strong, legible, and durable, it

is proper and useful to moisten the said thin paper, which is to receive the copy or impression, with the following liquor, instead of water or other liquid, and to proceed in all other respects as is above directed; or to moisten the said thin paper with the following liquor, and to dry the said paper, and when a copy of a writing is required to be taken, the said paper, thus previously prepared and dried, ought to be moistened with water or other liquid, and to be proceeded with in all other respects as has been directed. The said liquor to be used for moistening the said thin paper, or for preparing the said paper previously to its being used, is made in the following manner: take of distilled vinegar two pounds weight, dissolve it in one ounce of the sedative salt of borax; then take four ounces of oyster-shells calcined to whiteness, and carefully freed from their brown crust, put them into the vinegar, shake the mixture frequently for four and twenty hours, then let it stand until it deposits its sediment; filter the clear part through unsized paper into a glass vessel, then add to the said mixture or solution two ounces of the best blue Aleppo galls bruised, and place the liquor in a warm place, shaking it frequently for twenty-four hours; then filter the liquor again through unsized paper, and add to it, after filtration one quart, ale measure, of distilled or other pure water. It must then stand twenty-four hours, and be filtered again if it shews a disposition to deposit any sediment, which it generally does. The liquor, thus compounded and prepared, is to be used as hath been directed.

N. B. In place of the vinegar, any other liquor impregnated with a vegetable acid may be used; and, in place of the galls, oak-bark, or any other vegetable astringent, or substance which is capable of becoming black or deep coloured, with solutions of iron; and in place of the oyster-shells, any other pure calcareous earth may be

used. But if the impressions are not wanted to be very black, and the writing-ink is good, water itself may be used to moisten the thin paper, as herein first directed. It may be found necessary to add more or less water, in the preparation of the above liquor to be used for moistening the thin paper, or to vary the proportions of the other ingredients, according as they are more or less perfect or strong, or as the impression is required to be more or less deep coloured. The writing ink which I use for letters or writings intended to be copied, is prepared as follows: take four quarts, ale measure, of spring water; one pound and a half avoirdupoise weight, of Aleppo galls; half a pound of green copperas or green vitriol; half a pound of gum arabic; four ounces of roach allum; pound the solid ingredients, and infuse them in the water six weeks or two months, during which time the liquor should be frequently shaken; strain the liquor through a linen cloth, and keep it in bottles, closely corked for use." Rep. Arts. 18.

Common ink may be made fit for records by grinding up with it about one sixth part of the weight of the copperas employed of calcined lamp black (the calcining in a close vessel improving the colour and rendering it less oily.) Or indigo, or Frankfort black, or even a very finely powdered charcoal may be substituted; or some common China or Indian ink may be dissolved in it. The liquid also should be half vinegar and half water, which sinks deeper, and the proportion of gum should be somewhat encreased.

I do not find that the directions of Van Mons, Desormaux, or Ribaucourt, offer any substantial improvement on the preceding recipe which is nearly Dr. Lewis's. The blue vitriol I add to give a blue tinge with the logwood: these two ingredients composing the false blue dye.

No experiments sufficiently decisive have been made on the preference that ought to be given to cherry or plum-tree gum, gum tragacanth, gelatine of flour, common glue, isinglass, or fish glue over gum arabic or gum senegal. Lewis says that all the vegetable gums answer nearly the same purpose, but that the animal glues do not. Of this I am by no means persuaded. Sour ale and water, makes a very glossy ink. If China or Indian ink be dissolved in a large proportion of water, the black sediment appears to be lamp black or ivory black, and the liquor putrefying, indicates that the colouring matter is suspended by animal jelly.

The preceding recipe for writing ink, contains more galls than are necessary to the highest degree of blackness, but not more than are necessary to the durability of the ink. For present purposes, one third of the galls may be omitted.

Common ink powder is thus made. Galls in powder two parts by weight; green vitriol in powder one part; gum arabic in powder one part; sugar one fourth of a part. These should be dissolved in water and vinegar, of which the latter may be in the proportion of one third, to the water.

A few cloves prevent the mouldiness of ink. I think cotton in an ink-bottle tends to preserve the colour.

As the fugitive part of ink is the gallic acid, old writings that have become illegible through time, may be rendered legible, by brushing them over with a solution of nutgalls in water; or by a dilute solution of prussiat of potash.

The colour of common ink is completely destroyed by oxymuriatic acid. This effect is counteracted by rubbing up some lamp black with the ink.

The ink of the ancients, was of the same nature with China or Indian ink, being made of lamp black (probably calcined to improve the colour and diminish the greasi-

ness) and suspended by means of glue. Their best glue was made by boiling bulls ears in vinegar and water.

China or Indian ink, can be washed off the paper by the patient application of a brush and warm water. Hence, Mr. Sheldrake has proposed a mixture of turpentine varnish thinned by oil of turpentine and coloured by lamp black. Or better by dissolving gum-copal in oil of lavender, and rubbing it off with a small quantity of lamp black. I have repeatedly dissolved gum-copal by means of gentle heat and much patience, in oil of turpentine, and oil of rosemary, and still more easily in oil of pennyroyal and oil of burgamot, and some other of the essential oils. This recipe may answer for some curious purpose, but it is not calculated for common use.

Red ink is made with cochineal and gum arabic dissolved in vinegar and water. Or by brazil, braziletto or nicaragua wood in the proportion of one ounce and a half to a pint of water, containing a quarter of an ounce of alum and half an ounce of gum arabic. *Blue* ink. Indigo and gum arabic. *Green* ink, dissolve in vinegar and water, crystallized verdigrease till the colour be sufficiently strong; thicken with gum arabic. *Yellow* ink; is made either by a decoction of saffron, or of French berries (grains d'Avignon.)

The common *marking ink* used for these thirty years in Manchester to mark the corners of the unbleached goods, is a solution of silver in nitrous acid, which when fused by fire, is the lunar caustic of the shops. Take of this one drachm, dissolve it in 4 times its weight of rain water: thicken it by putting in about half a drachm of gum arabic. Moisten the part you mean to mark, with a solution of one drachm of pearl ash in about six times as much water; dry it, and then write with the ink. This ink is used by the dyers and printers of cotton goods previous to bleaching, because neither acids or alkalies discharge the stain. But

for linen already whitened and made up, as shirts, table linen, &c. a solution of iron in nitrous acid thickened with gum arabic, is just as good: for although it may be discharged by the skilful application of acids, it will never wash out. Or a few drops of the nitrat of silver may be added to the nitrat of iron. The nitrat of iron does not require the previous use of the solution of pearl ash, as it is not so corrosive when fully saturated, as the nitrat of silver. If linen be marked with well-dyed blue thread, or with thread dyed a true turkey-red, no washing will discharge the colour.

PRUSSIAN BLUE.

The methods of making this pigment are kept secret in England and this country, I shall therefore present my notes on the subject with remarks on the processes I have collected.

I have repeatedly made it myself thus. Dry thoroughly in an iron vessel and powder grossly, any quantity of fresh blood. Dry thoroughly and powder also a quantity of pearl ash equal to the powdered blood. Mix them, and calcine them in a low red heat in a crucible with a loose cover until all smoke and flame ceases: then make the cover fit close, and calcine in a full red or nearly white heat for half an hour. The crucible should not be more than two thirds full, as the mixture is apt to swell. Empty the contents of the crucible into warm water in the proportion of a quart to four oz. of the mixture. Pour on again as much warm water: mix and filter the solutions. Dissolve of sulphat of iron (green vitriol) and of alum, of each a quantity equal to one half of the pearl ash employed. Pour the solution of alum and green vitriol mixt together, gradually into the solution of blood and alkali: both solutions are better for being warm, but not boiling hot. Stir it well. Let the sediment settle. It

will be of a dirty greenish colour: wash it. Then digest it for 2 or 3 days in diluted muriatic acid, (spirit of salt one part, water two parts.) The colour by this means gradually becomes blue, because the muriatic acid dissolves the yellow oxyd of iron which is not combined with the prussic acid. Wash it repeatedly. Dry it on chalk stones, paper, linen, or any other mode of draining off the water. Spread it thin to expose it to the air. I have kept the lixivium of blood and alkali (prussiat of potash) for a year and a half in bottles, and used it to make prussian blue with equal success as at first. Chippings of hoofs answer equally well with blood.

The more alum is put in, the more the colour is diluted, but it seems to be of use also, to save the muriatic acid.

In Philadelphia, hoofs and refuse cuttings of leather are calcined together with potash in a large iron vessel, but I do not know the proportions. My own experiments persuade me that more than one part or at the most, one part and a half of potash, to one part of animal charcoal by weight, is too much: but I believe the common proportion now is one part and a half of potash. The vessel in which the mixture of solutions is made, should be large, and the solution of copperas and alum gradually added, on account of the effervescence.

Another. "Heat the iron calciner red hot; then put into it one hundred weight of horns and 25 lbs. of pot or pearl ash, the horns will immediately begin to smoke violently; this inconvenience is considerably lessened by setting fire to the smoke with a bit of lighted paper, it will continue to burn at the mouth of the vessel for some hours. The fire is to be kept up or rather increased. In about two hours time, the horns will be considerably calcined, and must then be frequently stirred with an iron poker: after this has been continued for a length of time which is

much dependant on the degree of heat employed, the matter begins to make a considerable hissing noise, it is then to be constantly stirred until it becomes fused, then take it out of the calciner with an iron ladle and put it into any convenient iron vessel to cool. If the process has been properly conducted, it will appear in a cake of a dark dull green, the texture of which is much like liver of sulphur, Hepar sulphuris. This mass is to be broken in pieces, thrown into water and left in a covered vessel for two days to dissolve. 45 lbs. of alum and 15 lbs. of green copperas are dissolved in boiling water and left to settle. The clear liquor is decanted and made boiling hot, and the lixivium is likewise to be decanted and mixt with the other solution by putting alternately four parts of the alum and copperas liquor, to one part of the lixivium. The mixture is to be well stirred on each addition as an effervescence will take place, which without that caution would be likely to rise over the sides of the vessel. The prussian blue precipitates of a dark dull green, the liquor is then to be drawn off as close as possible, and more clean water added: the ablutions are to be repeated till the precipitate puts on the appearance of a very fine blue and is thoroughly edulcorated, which generally takes sixteen washings; it is then to be put on filtres, and afterwards to be dried on chalk stones.

(I have not noted my authority for the above receipt, but I believe it is from the relation of a manufacturer.)

Method of making prussian blue in Germany, by M. Baunach, Jour. de Ros. 1778, *part* 1, *p.* 312.

Take the horns and hoofs, of animals, the waste cuttings of leather, the latter in equal quantity with the former. Reduce them to small pieces, put them in a tubulated iron retort, and set this in a reverberatory furnace. Adopt a hogshead as a receiver: distill while any thing comes

over. The produce in the hogshead will be fetid oil, and volatile alkaline liquor. The residue in the retort is taken out, and broken to pieces. It is then put into an iron pot set in brick work and mixed well with three times its weight of potash. They operate commonly upon 10lbs. of the coaly matter, and 30lbs. of fixed alkali. The pot is heated gradually for an hour; then the heat is raised till the contents are fused. This operation lasts 12 hours, the matter is kept stirred all the time with an iron rod, when the matter thus fused gives out a smell of liver of sulphur, it is drawn red hot from the pot, thrown into water and boiled therein for half an hour. It is then poured off and fresh water boiled upon it to extract all the ley, which is filtered through cloth. Four parts of alum and one of green vitriol are then dissolved together and filtered. This is precipitated by the ley, and the precipitate left to dry.

Some manufacturers proceed thus. Take 6lbs. parings of skins, as much hoof and horns cut small: add 10lbs. potash: put them in an iron pot: let them macerate covered with water for 8 days, evaporate the water: put the mixture in a large iron pot, in which you have previously dissolved 2lbs. of crude tartar. Continue the fire till the substances are perfectly calcined: lixiviate. Then dissolve 5lbs. green vitriol and 15lbs. of alum water, and put this solution and the ley together.

The objection I have to the above recipes, is that the quantity of alkali is too much for the animal matter, and the alum and copperas also in too great proportion, but they bear the stamp of actual processes. M. Baunach's method of saving the volatile alkali seems to be economical, but I doubt whether there be not a loss of prussic acid.

The cheapness of hoofs, horns, and leather clippings in Philadelphia, makes this manufacture a desirable one

to be carried on there. In England, these articles are 3 or 4 times the price, and the alkali also is much dearer. The actual process in Philadelphia is not essentially different from those above described: the hoofs are calcined in an iron pot: potash is added and calcined in a strong heat with the charcoal of the hoofs: the mixture is washed in hot water, and a mingled solution of green copperas and alum is gradually added. The dirty-coloured mass, is cleared by digesting it with dilute vitriolic or marine acids, of which I am persuaded the latter is the best. The actual proportions, as it was improper for me to enquire, I am unable to communicate. My own opinion is, that one part and a half of alkali to one part of animal charcoal (that is after the blood, the hoofs, the horns, and the leather are charred) and one part and a half of green vitriol and as much alum, are enough for a fine colour. The colour is never perfect till after a few days exposure to the air.

Experiments are wanting to shew, 1st. What proportion of potash, the animal charcoal can saturate. 2ly. What proportion of sulphat of iron, the prussian alkali can precipitate. 3ly. Whether the prussian alkali throws down the iron or the earth of alum in preference, and in what proportion. 4ly. Whether the alum contributes to dissolve the yellow oxyd of iron.

It appears to me, that alum has the following uses: it is thrown down, not by the prussiat but by the carbonat of potash, and therefore prevents much of the yellow oxyd of iron from being precipitated: it adds to the body and to the brilliancy, and to the cheapness of the colour, but not to the depth or intensity of it.

COLCOTHAR: CROCUS MARTIS: SAFFRON OF MARS.

This is an oxyd of iron, made red by exposing it to heat, and used for polishing brass and iron utensils, and making razor straps. It is made thus. Take green vitriol and calcine it alone in a heat sufficient to drive off all the water and acid. It then becomes a brownish red substance which must be washed, levigated and sifted.

Or, green vitriol is precipitated by carbonat of potash (pearl ash) the precipitate washed, dried, and calcined till it becomes red, is then levigated and sifted.*

DR. ALLISON'S PATENT SPINNING MACHINE.

The annexed plate exhibits a perspective view of a very portable machine, chiefly designed for spinning w ool; invented and patented by the rev. doctor Allison, of Burlington, New Jersey. The principal object of the inventor was to facilitate domestic manufactory, literally; or that of private families. The machine is exceedingly simple in its construction, occupies very little room, is readily managed, and has already been introduced into several farm houses, where it is found to answer all the purposes designed by it. Although principally designed for wool, yet it is found that it will spin cotton when carded into rolls, with great facility.

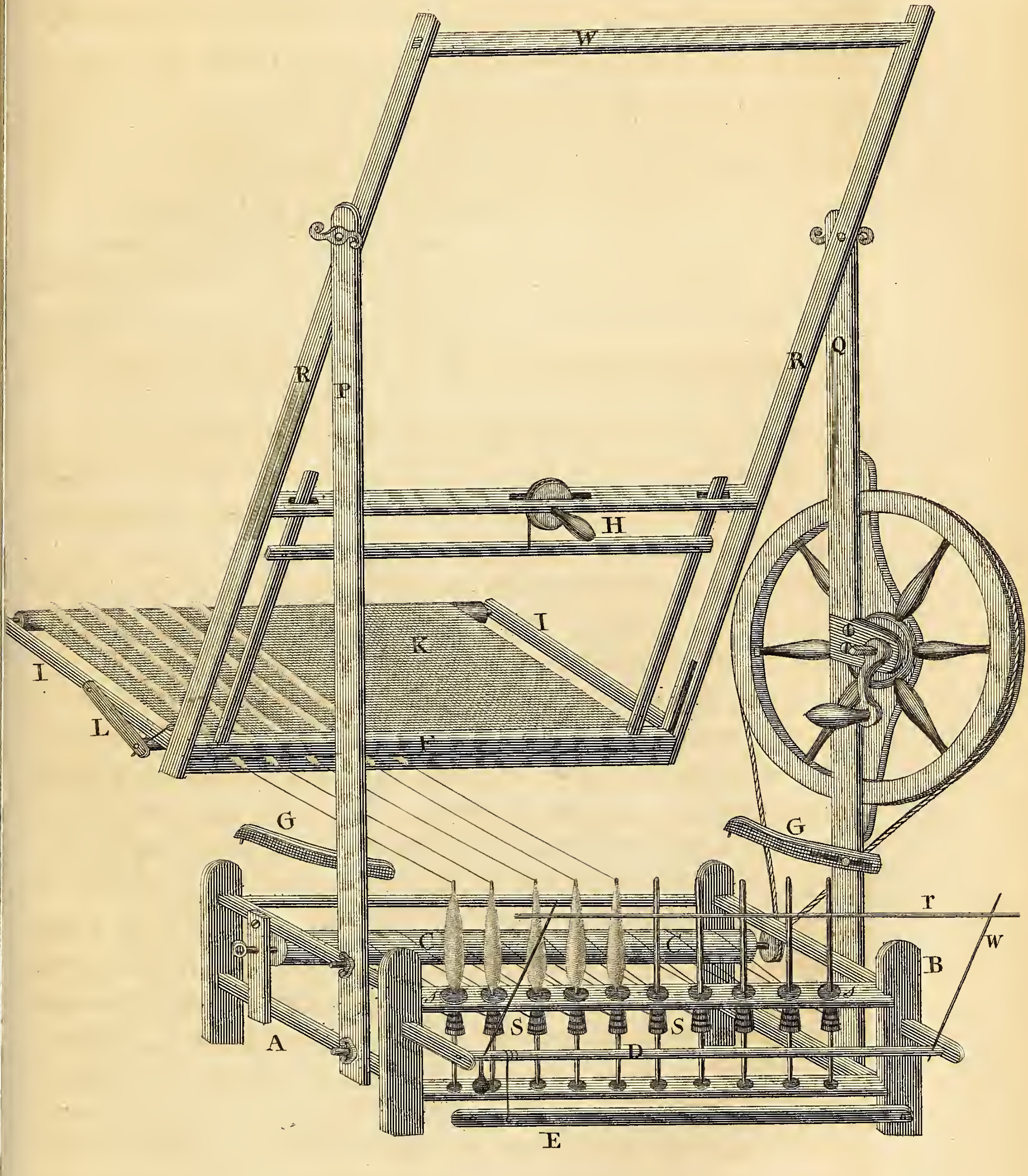
Explanation of the plate. A, B, The frame or body of the machine, with the spindles S S, which are turned by bands passing round their whirls, and over the cylinder C C. Five of the spindles are represented with yarn on them, and the other five without any, so as to shew the wooden skeefs or case, into which the steel spindles are firmly inserted. At the lower part of the skeefs are small circular pieces of wood, tin, &c. called sluffs, S S slipped loosely on the skeefs, to form the cops or broaches of yarn on—D is a small wooden roller, supported by gudgeons which play in the two pieces which project from the posts. Near each end of D is a small wire w, supporting a light rod r, which

* One hundred parts of iron, yield about 145 parts of red oxide.

acts as a traverse rod to distribute the yarn on the spindles as they are winding up; this rod is worked by the foot by means of a cord, near one end, wound round it, and descending to the foot-piece E, and is thrown back again by a small pea, or balance weight, near the connecting cord, when the pressure of the foot is taken off the foot-piece—P A, are upright posts which support the swing R R by two screw-pins, passing through the upper part of them. F is a clamp or slide, at the lower part of the swing, which slide is raised by turning the handle H and its pully, round which a cord passes and connects with the frame of the slide. I I, is a frame screwed to the sides of the swing, by iron straps, and carries two rollers, round which the feeding cloth K moves. The roller next the clamp, has a friction wheel at each end, and is supported by two levers L L, which work on pins at the sides of the frame I I; and are attached by strings, going from the front end of the lever, to the slides so that they rise and fall with it. G G are two gage stops moveable on the posts P Q, so as to set them to spin finer or coarser. W, is a counter balance weight of cast iron, to lessen the labour of throwing out the swing.—The size of a machine of ten spindles is about three feet long and two wide; the upright posts are six feet high; and the swing answerable to the other parts.

When the machine is to be used: the wool must be well carded into rolls, by a carding machine; and laid evenly on the feeding-cloth, with one end under the clamp or slide, which being fitted, by tongues into the grooves of the under part, holds the rolls firm. A small piece of the end of the rolls, next the spindles, must be drawn and twisted by the fingers, so as to tie them to the yarn on the spindles. Then with your right hand grasp the handle of the main wheel, and with your left the handle of the swing: turn the handle of the swing so as to raise the slide, which will press the friction wheels up against the gage-stops, and turn the front roller so as to bring forward the feeding cloth as you push out the swing; until the stops on the levers L L strike against the projecting part of the gage-stops G G, and prevent the swing from going out until you let the slide fall, which will confine the given length of the rolls. Before you proceed further to throw out the swing, gently turn the wheel, so as to give a slight twist to the roll to strengthen in for drawing: then with your left hand push out the swing, and with your right turn the wheel moderately, until you have drawn out the yarn to the

A perspective view of D.r Allisons domestic Machine for spinning Wool.



Tiebout & Lawson.

length determined on for each stretch, and then give it the required twist. Previous to your returning the swing for winding up the yarn, gently turn the wheel, a very small distance backward, to unwind the yarn a little way from the spindle, then tread on the foot piece which will cause the traverse rod to distribute the yarn down the spindle so as to form your (torn) you are returning the swing with one hand, and the spindle with the other, to wind up the stretch that had been spun. When the foot is raised from the foot-piece, the pea, or small balance weight from the roller D, will return the traverse rod to its place.—Should a strand break in pushing out the swing, do not stop to mend it until you have returned the swing, and then tye it—A little practice will render the use of the machine familiar and easy——A child may be employed to piece the rolls.

NUTRITION OF VEGETABLES.

(Concluded from page 303.)

These experiments show the extreme facility, with which the oxydes of lead are reduced, and the obstacle that carbonic acid opposes to this reduction.

As these first attempts did not afford me the result I sought, I availed myself of an old experiment of Huyghens, who, in 1672, put some earth into a bottle, corked it up, and found it produce such a quantity of plants, as almost to fill the bottle, without having had any fresh air admitted to it. Accordingly I procured six large flint bottles, most of which were square : filled them in part with very fine white sand, which I deprived of all calcareous earth by washing with weak muriatic acid ; and moistened this with distilled water. The remainder of the bottle was filled with atmospheric air freed from carbonic acid.

In these bottles having sowed 460 seeds of white mustard, I closed them very accurately, and placed them a few inches deep in a moist soil. Vegetation soon commenced, and considerable verdure was produced.* After six weeks growth my plants were

* It may be supposed, that these seeds did not germinate with as much vigour, as if in the open air. This however I do not think must be ascribed to the want of oxygen ; for by trial of the air with a sulphuret before and

liberated from their prisons, washed with great care, and dried. In this state they weighed 9 gram. [140 grs.] I filled a phial with them, which terminated in a narrow tube, and exposed it gradually to a strong heat. Thus I obtained 4 grammes, 8 dec. [74 grs.] of coal. But as I supposed this coal might still contain a little sand, I incinerated it, and found 3 gr. 3 dec. [51 grs.] of alkaline ashes. Consequently there was 1½ gr. [23 grs.] of pure carbon.

In a very small vessel I distilled 460 white mustard seeds, and from this highly hydrogenated seed I obtained only 4 gr. [62 grs.] of coal, which lost near half its weight by calcination. Hence it follows, that 460 mustard seeds acquired in close vessels upwards of a gramme [15½ grs.] of pure carbon, which appeared evidently to have been formed at the expense of water, and probably of light.†

Geological facts too seem to shake that theory, which ascribes the carbon found in vegetables to the small quantity of carbonic acid contained in the atmosphere. How indeed can so small a portion of this acid, scarcely amounting to a ten thousandth

after the experiment, its proportions appeared to be nearly the same. This is agreeable to the experiments of Hassenfratz, who convinced himself, that plants do not diminish the quantity of oxygen in a confined atmosphere; and I am iniclined to think, that oxygen acts on plants merely as a stimulant, which is not indispensible, for Homberg found different seeds germinate in the vacuum of an air-pump. The principal cause that prevents the complete developement of plants in close vessels, appears to me to be owing to their abundant perspiration, which throws out the excrementitious fluids, that are so fatal to them even in the open air, as to render a certain space among their neighbours necessary to their vigorous growth.

† To satisfy myself, that plants can appropriate to themselves the elements of water, so as to constitute their different materials, only by their own organic action combined with that of light, I caused a given quantity of seed to grow in compleat darkness, and at the common temperature of the air. They shot out long white filaments, at the extremity of which were the two seminal leaves; but nothing more appeared. After desiccation these plants weighed less than the seeds whence they sprung: which appeared to be owing to their having lost carbon in this languishing state, instead of acquiring it.

But the mode of action of light on vegetables remains yet to be known. It appears however, that it enters into combination with them, and that to this combination is owing the green colour of their leaves, and the variety of hues admired in their flowers. Yet Mr. Humboldt has found green plants growing in deep and dark mines, the atmosphere of which contained

part of the air, explain the formation of those vast mines of pit-coal, which still retains the marks of those organized substances whence it originated, and the organic origin of which is sufficiently announced by its composition of carbon, hydrogen, oxigen, and azote? But without appealing to these ancient productions of the vegetable kingdom, buried in the earth in such abundance, we need only cast an eye on its surface, to satisfy ourselves that nature must have taken other steps to produce carbon.

On the other hand, if, in the silent progress of vegetation, the elements of water concur with the solar light to produce charcoal by intimate combinations unknown to us, charcoal ought to contain hydrogen likewise; and this is confirmed by experience. If charcoal strongly calcined be urged in the fire with a substance that has an affinity for hydrogen, the charcoal is partly decomposed, and hidroguretted products are obtained. Mr. Berthollet mixed 30 gr. [460 grs.] of charcoal calcined in a forge fire with 20 gr. [309 grs.] of sulphur, and by distillation in a porcelain retort obtained more than 100 cubic centim. [391 lines] of sulphuretted hydrogen gas: and it appears to me to be probable, that if the experiment were frequently repeated with the same charcoal, it might be totally decomposed, a fact that it would be interesting to verify.

If oxigen in the state of gas be presented to the charcoal instead of sulphur, water is formed, as is proved by the experiments of Lavoisier on the combustion of charcoal, as well as by those of Mr. Hassenfratz: and analogous results are obtainable with metallic oxides, according to the observations of Cruikshank.

It even appears from the nice investigations of Messrs. Biot and Arrago on the refractive power of bodies, that the diamond, which has hitherto been considered as pure carbon, must contain a large quantity of hydrogen, which has the greatest refractive power of any substance yet observed in nature. These gentlemen intend to verify their conjecture by direct experiments, from which very interesting results may be expected. The existence of hydrogen in the diamond has been announced from other facts by Mr. Winterl.

From the chief facts that have been here mentioned, it follows:

a great deal of hydrogen. Does not this fact indicate something common between hydrogen and light, particularly when we observe, that these two fluids, the lightest in nature, seem likewise to produce analogous effects on some metallic oxides and salts?

1. That vegetables find in pure water every thing necessary for them to assimilate.

2. That vegetable mould in a state of compleat decay contains nothing soluble, and can only supply plants with water, which it retains abundantly in a certain state of division adapted to their nourishment.

3. That vegetables can grow in any substance, provided it have no action on them, and be perfectly insoluble in water.

4. That the organic powers assisted by the solar light, developes in plants substances that have been deemed simple, as earths, alkalies, metals, sulphur, phosphorus, charcoal, and perhaps too nitrogen, that probably will no longer continue to be the limits at which chemical analysis will stop.

5. That oxigen, hydrogen, and fire appear to be the only elementary substances, that serve to constitute the universe.

6. Lastly, that nature, in its simple course, produces the most various effects by the slightest modifications in the means it employs.

Machine for beating out Hemp seed and Flax seed, by Ezekiel Cleall. 23 *Nich. Jour.* 16.

SIR,

THE machine of which a model was sent to the society some months ago, must be used with eight flails, two on each arm, for beating out hemp seed.

When required to be used for beating out flax seed, the above eight flails must be taken out, and four beaters put in their place.

The height of the machine from the floor to the top of the board on which the flax or hemp is laid, is two feet; the breadth, two feet ten inches; the length of the board, four feet four inches; the length of each of the arms, from the axis of the machine, is three feet two inches; the flails for the hemp seed, two feet two inches long; the heights of the uprights, seven feet two inches; the beaters for the flax seeds, are each one foot three inches long, and seven inches broad.

The machine will thrash, in one day, as much hemp as grows on an acre of land, and other crops in proportion; and the work is

Mr. Cleall's Machine for thrashing Hemp

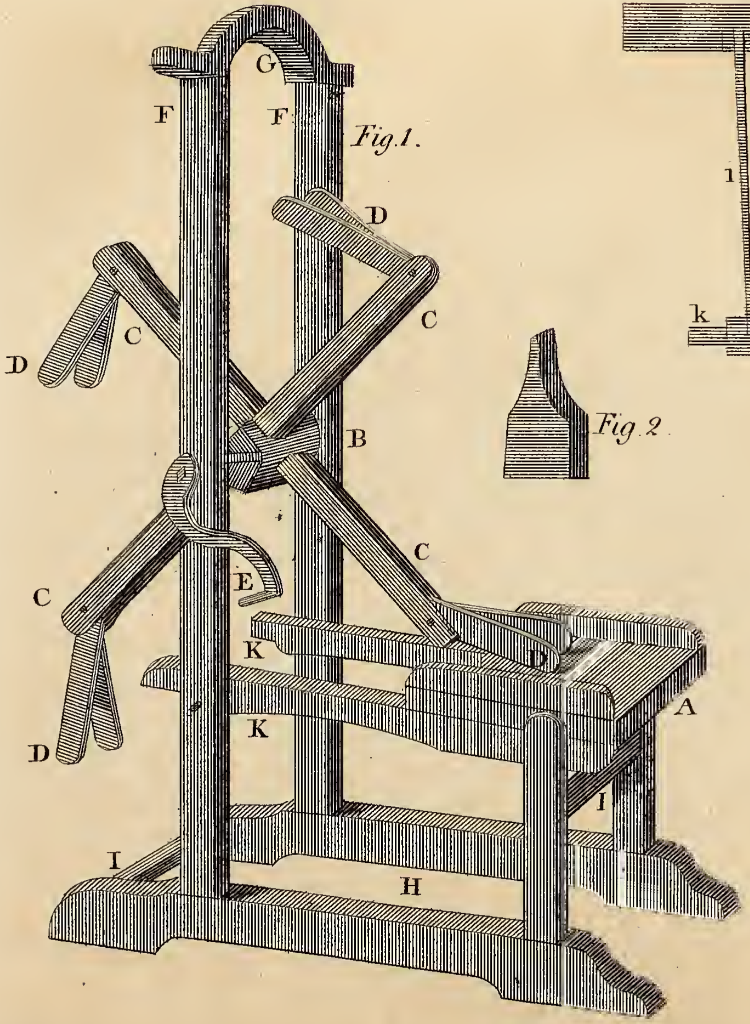


Fig. 1.

Fig. 2

Mr. Bond's Machine for breaking Hemp

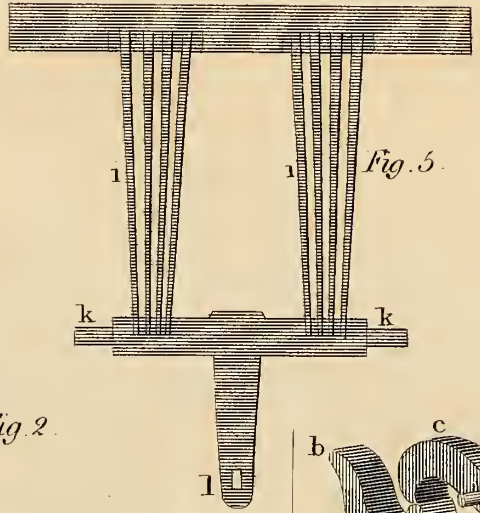


Fig. 5

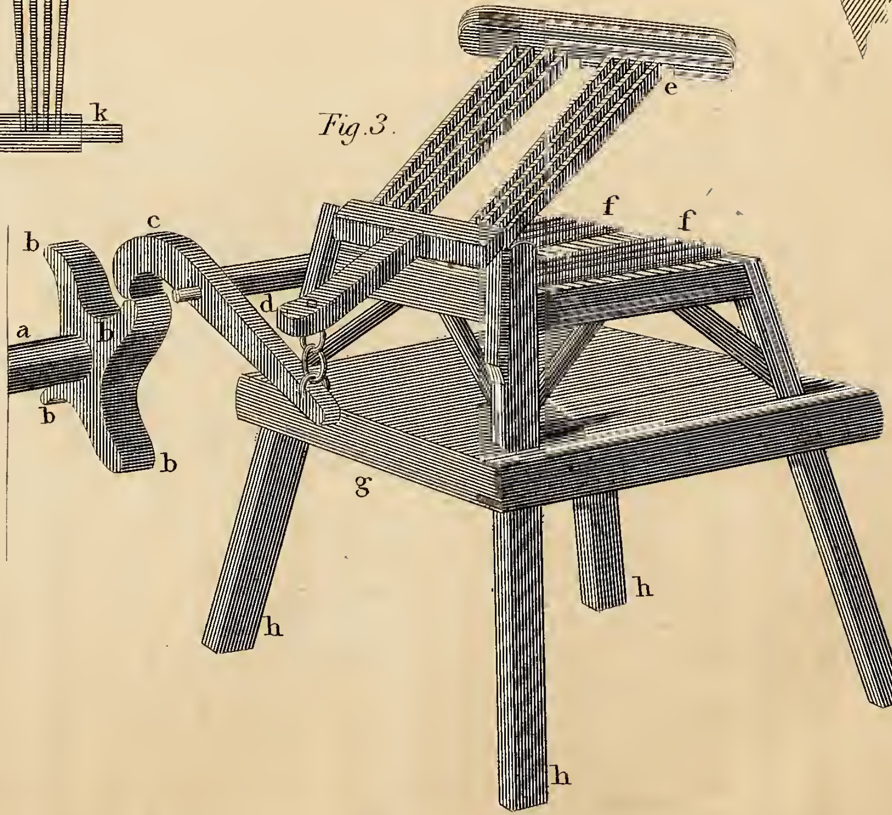


Fig. 3.

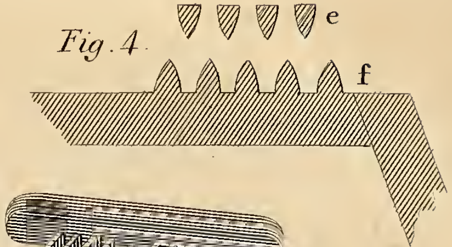


Fig. 4.

C. Tiebout Sc.

done with less than half the expense of thrashing in the usual way.

I am, Sir, your obedient servant,

EZEKIEL CLEALL.

Reference to the Engraving of Mr. Cleall's machine for beating out Hemp Seeds and Flax Seeds. Pl. II. *Fig.* 1, 2.

Fig. 1. Represents the machine for beating out hemp seeds, in which A is the table or board on which the hemp is to be placed; B the axis in which the four arms CCCC are fixed; DDDD, eight single flails, moving upon four pins near the extremities of the four arms; these flails diverge from the pins on which they move, so that two of them united on each arm are nearly in the form of the letter V. E is the winch or handle by which the machine is put in motion; F F, two upright pieces of wood to sustain the axle of the machine; G, an upper cross piece, to secure the uprights firm; H H, the two bottom pieces or sills, in which the two uprights are mortised, also the two smaller uprights which support the board or table A; I I, two lower cross pieces to secure the machine firmly; K K, two levers on which the table A rests, and by which it may be raised or lowered, as thought necessary, by iron pins, at K K, passing through these levers and the two uprights.

When the machine is used, the hemp must be laid on the table A, and moved about in different directions by the person who holds it, whilst another person turns the machine by the handle E; the flails D of the machine fall in succession on the hemp; as the axis moves round they beat out the seeds as different surfaces of the hemp are exposed on the table, and when the seeds are all beaten out from one parcel of hemp, a fresh quantity is applied upon the table.

Fig. 2. Represents one of the flax beaters, which is made of a solid piece of wood, one of which is attached instead of the two flails, to every arm, when the machine is employed for beating out flax seeds, as they require more force to separate them from the flax plant.

Machine for breaking Hemp, by W. Bond, Esq. of Canada. Ibid. 18.

In all new countries where labourers are scarce, we find many contrivances calculated for the purpose of reducing labour, more for the sake of expedition than ease; such, for instance, as the saw mill, the hoe, ploughs, scythe and cradle for cutting and ga-

thering grain, the wooden machine (drawn round by one horse), for thrashing grain, the iron shod shovel, drawn by oxen, and held by two handles, as a plough, for the purpose of levelling the roads, &c. Nor are the Americans, or other settlers in this country, fond of any work that needs violent exercise of the body; which the breaking of hemp in the old way certainly occasions, in consequence of requiring a cross motion of the arm, which makes the breakers complain of a pain about the short ribs on the side they hold the hemp; and on the opposite side a little under the shoulders, so that breaking of hemp in the old way is a great obstacle to its increased culture. To render labour, therefore, somewhat more easy and expeditious, is an object worthy the first attention, and I consider it practicable at a small expense, and have sent to the society, a model of a machine for this purpose.

I have observed among the clothiers' and fullers' machinery, great power and rapid motion proceeding from what is commonly called a dash wheel, erected across a stream of rapid water, the flies or float boards of which are fixed in the octangular axis, from fifteen to twenty-five feet in length, and from three and a half in depth, each fly. I have seen many corn mills in Upper Canada, with no other water wheels than such as the above described, which save a vast expense in raising dams, &c.

There are a number of streams in that part of Canada, which I have endeavoured to describe, (as to the practicability of the various ways of cultivation) that are well calculated for such wheels; and where these streams or rivers are not too wide, the axis of the wheel might be extended across so as to reach the land on each side, where I propose the breakers to be fixed to go by a tilt the same as a forge hammer. Such a simple piece of machinery would not cost more than 70 or 80 dollars, as little iron would be wanted, and timber we have for nothing; and when in motion would employ four breakers and two servers, from whom I should expect as much good work as fifteen or sixteen persons could possibly do in the old way, and that without much bodily labour.

Mills for breaking hemp, on the very same principle as that of a saw mill, as to motion only an addition of an iron crank, so as to run with two cranks instead of one, with something of a larger sweep than that of a saw mill, would be of vast utility in a neighbourhood of a large growth of hemp, and would not cost more than a common saw mill. As the breaks of the frame continue in motion the same as that of a saw mill, twenty men might be employed, who

would do as much as fifty or sixty could do in the old way, and with much more ease and pleasure to themselves; and this is not the only advantage that would result from such mills; it would cause something of a social meeting, which the youth would be particularly fond of. At such meetings all the defects respecting the culture and management of hemp would be examined into, and those who raised the best would become ambitious, and try to excel each other; thus we might reasonably expect, that Upper Canada would far exceed all other countries in the world for the growth of good hemp.

Reference to the Engraving of Mr. Bond's Machine for breaking Hemp. Plate. Fig. 3, 4, 5.

Fig. 3. *a* represents the axis of a water wheel, on which is fixed a trunnion of four lifters *b b b b*, each of which lifters raises in succession a lever *c*, which, by means of a chain connected with it, pulls down another lever *d*, and thereby raises the upper part of the double brake *e*. As each lifter of the trunnion passes the lever *c*, it allows the upper part of the brake to fall upon the hemp placed on the lower part of the brake *f f*; and by its weight, and teeth intersecting the teeth of the lower brake *f f*, the woody parts of the hemp plant are separated by repeated strokes from the filaments or fibres of the hemp proper for use. This completes the first operation necessary in the preparation of hemp. *g* is a table on which the woody parts of the hemp fall, and which gives security and strength to the frame; *h h h h* are the four legs or supports of the frame.

Fig. 4. shows a section of the teeth of one half of the double brake above mentioned: it is betwixt the upper and lower rows of these teeth that the breaking of the hemp takes place, by the repeated rise and fall of the upper part of the brake upon it.

Fig. 5. shows the upper part of the brake, in which *i i* shows the two rows of teeth, *k k* the two pins on which it is moved, *l* the part to which the chain which raises the upper part of the brake is attached. After the breaking of the hemp, it is wholly finished for use by scutching or swingling, an operation which may be either performed by the hand or machinery, and is easily executed by either mode.

The machinery for breaking hemp should be removed from the rivers previous to the beginning of the frosts.

COAL GAS.

It is now ascertained in England, that manufactories can be lighted cheaper, more conveniently, more neatly and more safely, by means of the inflammable gas from pit coal than by any other means. I do not believe that the act of extracting and burning this gas, is in a state sufficiently advanced as yet, to render it eligible for lighting dwelling houses. But the manufactories of New-England, of Philadelphia, of Pittsburgh, may use it with profit—it may be used for theatres——and (as I am persuaded) for a great deal of the kitchen-cookery of large taverns in summer time. It has not yet been applied in lieu of steam, as a moving power in fire-engines, but I think it will be.

In this country, every suggestion that brings forward the importance of COAL to the public view, is of moment: we know little of its value in Pennsylvania as yet. *All*, *all*, the superior wealth, power, and energy of Great Britain, is founded on coal mines. Coal mines produce manufactories; manufactories produce canals, turnpike roads and rail ways; these produce communication of interest, knowledge, and improvement all over the kingdom. Where coal mines are, there, and there only will manufactories flourish. Manufactories produce division of labour, corporal and mental energy; they banish idleness; they produce perpetual demand for, and bring into play chemical science, and the science of machinery. They have produced a class of men almost peculiar to England, the *civil engineers*, to whom the country has been more indebted than to any other class of citizens, dependant on their talents for their living. All rests upon coal.

Coal may be classed under two great divisions: the coal that burns with smoke and flame, bituminous coal: and the coal that does not burn with smoke and flame: stone coal, glance coal, anthracite, graphite coal. All the coal to the west of the west branch of the Susquehanna, is *bituminous* coal; this will yield abundance of carburetted hydrogen gas, and will charr or coke. The coal east of the north east branch of Susquehanna, burns without smoke, with little flame, contains no bitumen, abounds in carbon, and is an *anthracite*.

I present the reader with the two most approved methods of obtaining the inflammable carburetted hydrogen from pit coal.

Description of an Apparatus for making carburetted Hydrogen Gas from Pit Coal, and lighting Manufactories with it. By Mr. SAMUEL CLEGG, *of Manchester.* 23. *Nich. Jour.* 85.

DEAR SIR,

When your son was in Manchester, he called to see my nephew, Samuel Clegg's improved gas lights, and was desirous to have a plan of his method, which my nephew promised him, and I undertook to get it conveyed to you, I have accordingly, taken the opportunity of sending to the Society of Arts a plan and explanation of his apparatus.

He lighted a large manufactory in Yorkshire some years ago upon this principle, and has since lighted some buildings in this neighbourhood, and I believe he is the first person, who succeeded in rendering these lights free from the offensive smell which generally accompanies them. My nephew served an apprenticeship to Messrs. Boulton and Watt, of Birmingham, in the steam engine business, in which he is now engaged here on his own account, and has made considerable improvements in their construction.

I remain, dear Sir,

Your most obedient servant,

ASHWORTH CLEGG.

Manchester, May 18, 1808.

SIR,

Your esteemed favour I have received, and, according to your request, have sent you a fuller explanation of the gasometer and lamp, accompanied with farther drawings.

A gasometer, containing seven hundred cubical feet of gas, weighs about twenty hundred weight, and costs about two pounds ten shillings the hundred weight.

The whole of an apparatus complete, capable of supporting forty lamps for four hours, each lamp affording light equal to ten candles of eight in the pound, will cost about two hundred and fifty pounds. Each lamp consumes six cubical feet of gas per hour. I am happy to find, that the Society have honoured my communications with their attention, and I remain, with great respect,

SIR,

Your most obedient servant,

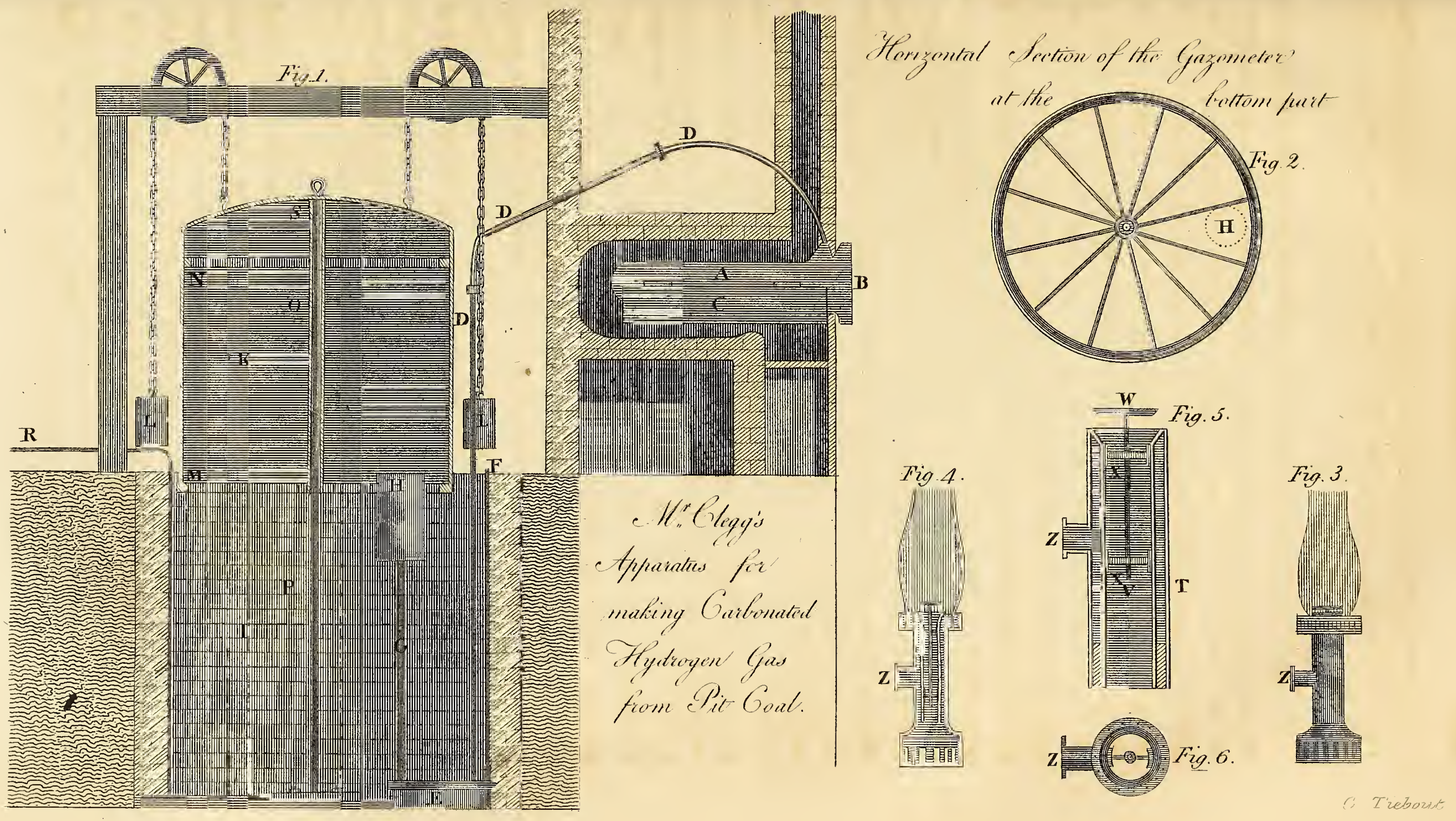
S. CLEGG.

Manchester, Aug. 12, 1808.

Reference to Mr. S. Clegg's Apparatus for extracting Carburetted Hydrogen Gas from Pit Coal. See Plate, figs. 1, 2, 3, 4, 5, *and* 6.

In fig. 1, A shows the cast iron retort, into which are put the coals intended to be decomposed by means of a fire underneath it, the heat of which surrounds every part of it, excepting the mouth or part by which the coals are introduced. The lid or iron plate B, which covers the mouth of the retort, is ground on, air tight, and fastened by means of a screw in the centre; C is a shield or saddle of cast iron, to preserve the retort from being injured by the intensity of the fire underneath it, and to cause it to be heated more uniformly. D D D represents the cast iron pipe which conveys all the volatile products of the coal to the refrigeratory of cast iron E, in which the tar, &c. extracted from the coal is deposited, and whence they can be pumped out by means of the copper pipe F. G is the pipe which conveys the gas to the top of the cylindrical vessel or receiver H; this receiver is air tight at the top, and consequently the gas displaces the water in the vessel H, to a level with the small holes, where the gas is suffered to escape and rise through the water of the well I, into the large gasometer K. The use of the vessel H is pointed out as follows, viz. If the pipe G reached all through the water, without passing into the vessel H, the gas would not be rendered pure or washed: and if part of the pipe did not rise above the water, the water would have free communication with the tar, besides exposing the retort A to a very great pressure, so as to endanger its bursting when red hot. This vessel or receiver H, in a large apparatus, is about eighteen inches diameter, and two feet long: the quantity of gas therefore which it contains, is sufficient to fill the pipes and retort when cool, prevent the pipe G from acting as a siphon, and expose the gas to the water without endangering the retort.

When the operation begins, the upper part of the cylindrical gasometer K, fig. 1, made of wrought iron plates, is sunk down nearly to a level with the top of the circular well I, and is consequently nearly filled with water, but it rises gradually as the gas enters it and displaces the water; the two weights L L suspended over pullies by chains keep it steady and prevent its turning round, otherwise the lower stays M of the gasometer would



Mr. Clegg's Apparatus for making Carbonated Hydrogen Gas from Pit Coal.

come into contact with the vessel H. There are two sets of these stays, one shewn at M, and the other at N.

There is also an iron pipe O, made fast in the centre of the gasometer by means of the stays, which slides over the upright pipe P, by which contrivance the gasometer is kept firm and steady, when out of the well; it likewise prevents the gas from getting into the cast iron pipe P, and the copper pipe R, any where but through small holes made in the pipe O at S at the top of the gasometer, where the gas is perfectly transparent and fit for use.

The pure gas enters the tube O at the small holes made in its top at S, and passes on through the tubes P and R to the lamps, where it is consumed and burnt.

The seams of the gasometer are luted to make them air tight, and the whole well painted inside and out, to preserve it from rust.

Fig. 2, shows a horizontal section of the lower hoop of the gasometer K at the part M, with its stays or arms, and the manner in which the iron pipe O, before described in fig. 1, sliding on the tube P, passes through the ring in the centre of the hoop. A horizontal section of the receiver H appears therein.

Fig. 5, shows a section of one of the gas lamps. The space between the outer tube T and the inner tube V, is to be filled with gas supplied by the pipe R, shown in fig. 1, where a stop cock is inserted for adjusting the flame, which gas passes through a number of small holes made in the outer edge of a circular plate shown at fig. 6, which unites the tubes T and V at their tops. V is the inner tube which conveys the atmospheric air into the centre of the flame: the upper part of this tube is made conical, or widening outwards, to join a circular plate with holes in it, a horizontal view of which is shewn at fig. 6. W is a button, which can be placed at a small distance above the mouth of the lamp, and its use is to convey, in an expanded manner, all the air which rises through this tube to the inner surface of the flame, which assists the combustion very much; this button may be set in any convenient distance above the tubes of the lamp, as it slides in the cross bars X X, by which it is supported in the inner tube.

A current of air also passes between the glass tube or chimney and the outer tube T, through holes made in the bottom of the glass holder, as in Argand's lamps: this surrounds the flame, and completes its combustion, as explained by the view, fig. 3, and

section, fig. 4, which have a glass upon each. Z Z Z Z, figs. 3, 4, 5, and 6, show the tube through which the lamp is supplied with gas from the pipe R, fig. 1.

Another apparatus for coal gas. Park's Chemistry. Plate.

The retort is filled and the cork taken out at D, which should be four inches diameter stopt with an iron plug. The tar and liquid partly runs down the tube with a stop-cock, next the furnace, but some of it mounts with the gas, and being cooled in the bent part of the tube runs down at the second tube with the stop-cock into the barrel B, which is inserted in an outermost barrel, and surrounded with water to condense the contents. The gas-holder C is suspended with its balance weight from the cieling. The rest is obvious. The gas holder and its containing vessel may be tin, copper, sheet iron, or simply casks. The perpendicular tube that rises into the chimney is designed to carry off the carbonic gas and water which rise at the beginning of the process, and which if mixed with the carburetted hydrogen would hurt the combustible quality of the gas sought for. Quere if a stop cock at D would not be useful for the first five or ten minutes? The tubes may be lead, tin, or copper.

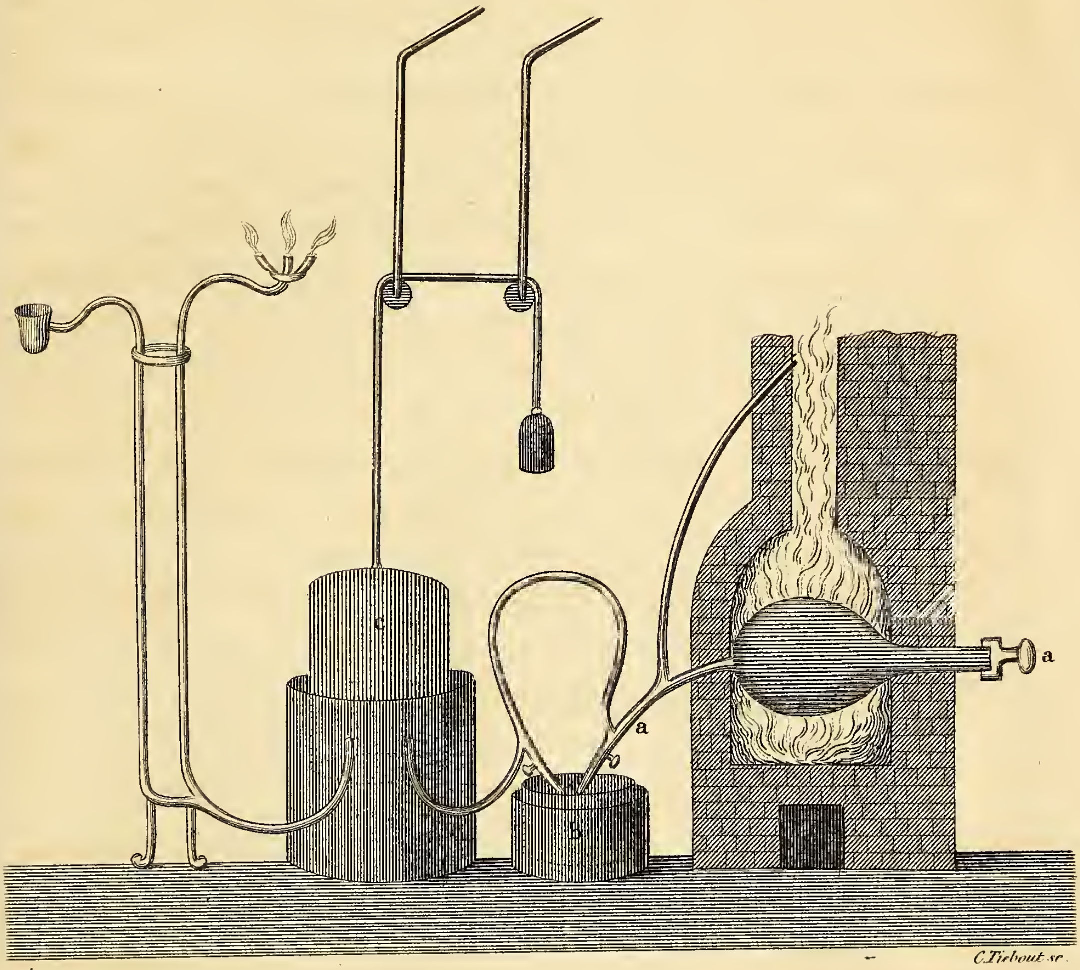
The distilled products will pay a great part of the expense.

ON MINERAL WATERS,

And watering places: particularly the Carlisle and York Springs in Pennsylvania, with a method of making artificial mineral water—By the Editor.

The resort to these situations, is partly on account of ill health, and partly for the sake of amusement, company, and variety. In England, on the continent of Europe, and in this country, the various motives of frequenting mineral springs are the same; and fashion is given to them, and medicinal virtues ascribed to them, rather by the votaries of pleasure, than the valetudinarian visitors. I do not pretend to deny, that laxative and tonic salts in small doses are frequently beneficial; but far more of the cures such waters are said to perform, are owing to good society, good scenery, amusement, novelty, change of air, incitements to pleasurable exercise without fatigue, and though last not least, to faith in the effi-

Coal Gas Apparatus.



cacy of the waters. All these circumstances are TONIC, and in a high degree so. No wonder, that large dilution, frequent exercise, and moderate doses of laxatives should occasionally do wonders to an invalid, whose digestive powers suffer under the indirect debility consequent upon habitual over action, and who has all the confidence necessary to enable the medicine to cure.

In the neighbourhood of Carlisle there are two mineral springs, resorted to greatly by persons in good health and in bad health; and of the one and the other wonderful stories are propagated in favour of their beneficial effects upon complaints of almost all descriptions. I have analysed these waters, and I proceed to give an account of them.

The *Cumberland Sulphur Spring*, on the estate of Wm. Ramsey, Esq. Prothonotary of this county, is situated about 5 miles north easterly from Carlisle. Carlisle is situated in the Cumberland valley; a limestone valley extending from Easton, on Delaware, through Cumberland county, Shenandoah, and southward beyond Staunton, in Virginia. About three miles from Carlisle, on the road to the sulphur spring, runs the Conodoguinet creek: half a mile before you come to this creek, the limestone disappears, and the surface soil is a schistus or rather a shale which extends from thence to the spring, and from thence to the north mountain as it is called, or the blue ridge. The spring is in a direct line not quite a mile from the mountain. The surface-stone of the neighbourhood, is mountain quartz, amorphous, striking fire with steel. The well belonging to the house, is dry through 14 feet of shale, such as is frequently incumbent on coal. There is no trace of limestone in the immediate neighbourhood.

The spring rises near a stream of good water; the quantity in summer time is such as would run with moderate velocity through a pipe of about half an inch bore. It smells and tastes strongly of a sulphureous gas, but has no other flavour or odour. The temperature is that of the common spring water. It feels soft and smooth to the hands on washing with it.

About three pints of this water boiled, yielded about one half its bulk of gas. This gas tastes and smells strongly of sulphuretted hydrogen: it deposits sulphur with oxymuriatic acid. The water itself blackens silver: it discharges the blue colour of muslin tinged with litmus: it discharges also in a great degree the colours of printed calicoes washed in it. It is therefore impregnated with sulphuretted hydrogen, holding sulphur in solution; and pro-

bably also with sulphuret of potash. From the experiments of Higgins and Kirwan, we know that alkaline and calcareous sulphurets are useful in bleaching.

Tincture of galls, and triple prussiat of potash, produced no change; it therefore contains no iron.

Oxalate of ammonia, hardly afforded a perceptible cloudiness. It therefore contains but little lime.

Carbonat of potash, threw down no magnesia: nor did carbonat of ammonia throw down any alumine, or the addition of phosphat of soda, exhibit any magnesia.

Nitrat of silver occasioned no precipitate; hence the water contains no muriatic salts.

Acetite of lead, produced a precipitate tinged blackish: indicating a sulphuret of potash or of lime.

Muriat of barytes detected no vitriolic acid combined or uncombined. The colour of litmus-rag, was not changed either blue or red; so that there appeared to be no uncombined acid or alkali:

A pint of the water gently evaporated to perfect dryness, in a queens-ware basin, by means of a spirit lamp, yielded barely 2 and $\frac{1}{3}$ grains of deliquescent residuum; which was half potash and half lime, both manifestly distinguishable to the taste, as well as by tests. This was repeated in Florence flasks, with the same results. These salts had doubtless been combined with sulphur.

Hence, the water in question, is water more pure than common, in every respect, except in holding half its bulk or there about of sulphuretted hydrogen gas, to which alone its medicinal properties are owing; for the very small proportion of alkalies and lime combined as sulphurets with the sulphuretted hydrogen water, cannot be regarded as producing much effect. The weather had been rather wet for about a week or fortnight preceding the time when the water was taken up; but there had been no rain for 3 or 4 days; nor did it seem, that the water was either more or less abundant than usual. So that the preceding experiments may be considered as made on the water, in its average state.

I conjecture, that the sulphuretted hydrogen, is produced by the decomposition of pyrites, deposited in the shale forming the roof of a coal stratum; though no trace of coal has hitherto been found or suspected in that neighbourhood. In many counties of England, the pyrites found in the roof of coal and the superincumbent stratum, is collected, placed in heaps exposed to the

air, and the green vitriol or sulphat of iron gradually formed by the oxygenation of the sulphur is washed off, and crystallized. Where sulphuric acid thus formed acts upon sulphuretted iron, sulpheretted hydrogen will be produced, and escape through any sinus or aperture in the earth, where there is room for it, whether in contact with water or not. Where there is no stream but moisture only, pyrites will become hot, if air can get to a body of it, and that heat may be communicated to the earth and the capillary streams in the vicinity of it, forming the warm waters, of Bath, Matlock and Buxton, of England, and the warm springs of Virginia.

In point of situation for *salubrity* of air, I know of no watering place in Pennsylvania that upon the whole, equals the sulphur springs in the vicinity of Carlisle, excepting the fashionable resorts on the sea shore.

The York sulphur springs, 17 miles from Carlisle, on the road to Baltimore through Hanover: are found in a transition country. I have remarked in the vicinity of the spring, much amphibolic rock (hornblend and quartz.) Amphibole upon the average contains about a twentieth of magnesia.

Dr. Cutbush analysed this water a year ago: he found that alcohol of galls, prussiat of potash, and succinate of ammonia produced no appearance of iron.

Muriat of barytes, produced a precipitate of sulphat of barytes.

Lime water, shewed no trace of carbonic acid.

Nitrat and sulphat of silver produced a muriat of silver.

Solution of soap produced a turbidness, shewing generally the presence of saline matter, oxalat of potash, threw down an oxalat of lime.

Caustic and carbonat of potash, threw down earthy matter soluble in muriatic acid; that is lime and magnesia.

Ammoniaco-phosphat of soda, threw down an ammoniaco-phosphat of magnesia. The quantity of gas contained, he had no opportunity of examining: but there is no doubt of its being sulphuretted hydrogen, nearly, but not quite so strong to the smell or the taste, as the water of the spring within five miles of Carlisle. It blackens silver like the latter water.

Dr. Cutbush on evaporating two ounces of the water, found a residuum amounting in sixteen ounces or one pint, to thirty two grains of saline matter: this would consist of 20 grains of epsom

salt or sulphat of magnesia, 4 grains of common salt or muriat of soda, 6 grains of gypsum or sulphat of lime; loss 2 grains.

I received toward the latter end of July two quarts of this water, from the spring; and as much from the pump; which latter I did not analyse. There had been rainy weather for some days, with an interval of 4 or 5 fine days immediately previous to the water being sent to me.

The water from the spring being tested with the same reagents employed by Dr. Cutbush, exhibited the same general appearances and indications, except that oxalat of ammonia threw down but a slight trace of lime.

Sixteen ounces avoirdupois, of the water carefully weighed, being evaporated, yielded not quite five grains of saline matter: this was repeated, in white queen's ware, and in florence flask, by means of the gentle evaporation of a spirit lamp: hence it should appear, that the water of this spring, is variable in the quantity of saline matter it contains.

The saline matter from these evaporations was reduced to fine powder, and a part thrown on a well lighted coal: there was no appearance of deflagration, and therefore there were no indications of nitrats.

On barely 5 grains from a pound of the water, finely triturated, I poured strong spirits of wine: this dissolved the muriats, and left behind the sulphats.

I boiled for a minute, the sulphats in pure water barely sufficient in quantity to dissolve them: this would separate the sulphat of soda, and the sulphat of magnesia. The residuum being dried into white silky crystals, was manifestly sulphat of lime; amounting to barely two grains in weight.

The alcoholic solution containing the muriats, was precipitated by nitrat of silver, and yielded about a grain of muriat of silver, indicating $\frac{1}{5}$ of a grain of pure muriatic acid: the nitrated solution precipitated by carbonat of potash, yielded about $\frac{1}{4}$ of a grain of precipitate, which readily dissolving in a minute portion of diluted sulphuric acid, and remaining permanently clear, was not lime, but carbonat of magnesia.

The solution of sulphats, precipitated by carbonat of potash, yielded also barely one grain of carbonat of magnesia. The remaining liquors would contain a grain or thereabout of alkaline sulphat which I did not think worth while to ascertain minutely.

The water of these springs, as is said, are diuretic, and of the

York spring, purgative. I could never find any effect of either kind, from a quart of these waters, or the waters of the Bedford springs, beyond what a quart of common water would produce; and I am well persuaded that the common pump water of the streets of Carlisle (which leave a residuum of 7 grains to the pint) and still more those of Philadelphia, according to my friend Dr. Hunter's analysis, contain a larger portion of cathartic ingredients than the waters of either of these medicinal springs.

Even according to Dr. Cutbush's analysis of the York spring water, one pound weight contains but 24 grains of purgative salt, for gypsum is not usually ranked in this class. That is 20 grains of epsom and 4 grains of common salt.

Now, the common dose of glauber's or of epsom salt when used as a cathartic is 1½ oz, or 720 grains: less than a fourth of this dose, or 180 grains, can hardly be deemed a permanent laxative: but to obtain this laxative quantity, near eight pints or eight pounds weight of water must be swallowed! Doubtless, if a man pours down his throat within 2 or 3 hours, a gallon of water of any kind, it must find its passage out again, either by diuretic, cathartic, or diaphoretic operation, or by all.

Still the fact is, and it is not to be denied, that people who stay two or three weeks at either of these springs, generally come away with improved health, provided they use exercise, dilute a good deal with the water, and live abstemiously in the articles of wine and ardent spirits. This may be accounted for

From the beneficial effect upon the skin particularly of the sulphuretted hydrogen gas; which certainly possesses virtues in cutaneous affections: nor are we as yet fully aware how much the general state of health depends on the state of the skin.

From the temporacy cathartic effect in a slight degree, which change of water frequently induces.

From the tonic effects, of change of air, change of society, change of scenery, change of amusements, from having the mind and the body pleasantly occupied, and from comparative temperance and great dilution among the male part of the society.

From early rising and the use of the bath, warm or cold, these are causes sufficient to account for all the beneficial effects received, without resorting to supposed ingredients or supposed qualities in these waters, which experiment carefully made, does not countenance. T. C.

A week after the preceding analysis, during which interval the weather had been fine and warm at the latter end of July and beginning of August, I received more water from the York springs. I evaporated carefully 2lb avoirdupois. I collected 14 grains of saline matter. It was dried, triturated, dissolved in alcohol, and the residue in hot water. The last watery solution, left a residuum of six grains, which was fully dried over a lamp, and proved to be sulphat of lime. To be quite sure of this, it was decomposed by double its weight of carbonat of potash. The sulphat of potash washed away, left the carbonat of lime perfectly soluble in dilute muriatic acid except about the $\frac{1}{4}$th of a grain of siliceous sand.

The water in which the sulphats were dissolved, had taken up a small portion of the sulphat of lime, which oxalat of ammonia detected, amounting to about $\frac{1}{2}$ a grain, there being one grain of oxalat of lime. The sulphuric acid was combined with potash as the crystals shewed: it was precipitated with barytes; and produced two grains of sulphat of barytes, dried over a lamp.

The alcoholic solution of the muriats furnished me with $1\frac{1}{2}$ grain of muriat of silver, $\frac{1}{4}$ a grain of alumina, and about $1\frac{1}{2}$ grain of carbonat of magnesia. As an accident happened to part of the filtering paper, on which this was dried, there *may* be an error of half a grain here, but I believe there is not an error to half that amount.

Hence the sulphur spring, 5 miles from Carlisle, contains in one pint by measure or 1lb by weight, about $\frac{2}{5}$ its bulk of the gas called sulphuretted hydrogen. It contains also one grain of pure potash united to sulphur, and as much pure lime, also combined with sulphur.

The sulphur spring, in York county, 17 miles from Carlisle, contains probably about as much sulphuretted hydrogen as the spring near Carlisle; but as the gas will not bear transportation, I have not the means of accuracy in this respect.

The York spring also contains in one pint by measure, or 1lb. by weight, according to the first experiment 5 grains of dried saline matter: yielding 2 grains of sulphat of lime, $3\frac{1}{2}$ grains sulphat of magnesia, about $\frac{1}{2}$ a grain of muriat of magnesia, and one grain of sulphat of potash. The excess above the five grains in this calculation, will arise from the greater quantity of water of crystallization in these salts in their common state, than in the dry state, in which I procured them. Thus, one grain of carbonat of magnesia is equal to ,65 of a grain of pure magnesia, which would make

four grains of crystallized sulphat of magnesia: for sulphat of magnesai contains 33,05 acid, 16,05 magnesia, and 50 water.

According to the second experiment one pint or 1lb. of the water, yielded seven grains of dried saline matter: which when fully crystallized, would yield nearly as follows:

Of sulphat of lime (gypsum) $4\frac{1}{2}$ grains.

Of sulphat of potash $2\frac{1}{2}$ grains.

Of muriat of magnesia $1\frac{1}{2}$ grain.

Of muriat of alumine $\frac{3}{4}$ of a grain.

Hence not only the quantity, but the proportions of the salts in these waters, is apt to vary; owing in great part to the different states of decomposition of the amphibole, and other stones, through which the waters pass, as well as to the wetness or dryness of the season.

The common pump water of Carlisle furnishes 7 grains to the pint of dried saline matter consisting chiefly of sulphat and carbonat of lime. It is apt for a few days slightly to affect the bowels of strangers not accustomed to limestone water.

The best method of combining the Seltzer water with a laxative proportion of the purgative salts is the following; which will enable every body to make at will, a mineral water, impregnated with cathartic qualities in any proportion that the palate will bear or the bowels will require, combined with the lively, sparkling qualities of the Seltzer water. Take of supercarbonat of soda, or even the common carbonat 20 grains; of the common carbonat of magnesia as much, put them in a strong black quart bottle; fill it nearly but not quite full of water; having previously ready a cork that will fit it. Pour in the quantity of strong vitriolic (sulphuric) acid, that you know from previous experiment will barely neutralize that quantity of saline matter. Cork the bottle, and tie down the cork instantly. The carbonic acid gas will thus be combined with a solution of glauber's and epsom salts, which may be kept in a cool place. In the same manner the dose may be altered or diminished, or sulphat of iron in the proportion of 3 or 4 grains may be added if the symptoms of the patient require it, and a mineral water produced more efficacious than any that nature presents to us. T. C.

LETTER FIRST, TO THE EDITOR.

QUÆDAM DE VINO. ON WINE.

Ecclesiasticus ch. xxxi. v. 27, 28, 29. "Wine is good as life "to a man if it be drank moderately: what is life then to a man "that is without wine? for it was made to make man glad. Wine "measurably drank, and in season, bringeth gladness of the heart, "and cheerfulness of the mind; but drunken with excess, maketh "bitterness of the mind, with brawling and quarrelling."

I could produce many parallel passages to the above, from books of still higher authority than the wisdom of the son of Sirach. The history of Noah, the fable of Abimelech, the marriage of Cana, the disputation in Esdras, &c. are all authorities to shew, that the moderate use of wine, even for convivial purposes, has received the highest sanction that authority can give it; and they shew too, that we are not called upon to renounce the gratifications of appetite, when they can be enjoyed with prudent restraint, and without injury to ourselves or to others.

Having then presented you, my friend, with some preliminary observations that bear upon the science of good eating, permit me to offer you some remarks that lead to the science of good drinking: for like Castor and Pollux they are strongly allied to each other, and when the dishes set, the decanters rise.

I shall not dwell upon the wines of the ancients, the Falernian, the Formian, the Cæcuban, the Massican, the Calenum, the Aulicum, the Lycean, the Chian, the Egyptian (Marœoticum) the Sabinum—for we know too little about them except that they were generally estimated somewhat in the order here mentioned as we find from Horace's *vile potabis modicis Sabinum cantharis*, and some other odes. Some wine has been found at Herculaneum and Pompeii, but not enough in quantity, or in a state to judge of its quality.

In fact, the ancients knew little on the subject; they had no system that I can find of keeping their wine: they had no glass bottles, their wine was kept, in casks, in jars, or in leather bottles.*

I do not precisely know without more search than the subject is worth, what were the distinctions between the *Testa*, the *Cadus*, the *Lagena*, the *Amphora*, in which they kept their wine: or between the *Ampulla*, the *Urceus*, the *Cantharus*, the *Diota*, the *Ciborea*,

* This explains the scripture passage, "For what man putteth new wine into old bottles?" Their new wine being apt to ferment.

(Squash or Gourd?) which seem to be the demijohns filled for a drinking bout; or the *Pocula*, the *Cyathi*, the *Vitrea*, the *Chrystallina*, the *Murrinæ*, out of which they drank; and of which, the Cyathi were of the smallest size, as I think in opposition to Dr. Adams; the Vitrea and the Chrystallina being of late date.

They had, as all well regulated communities ought to have, some repository for the sovereign power, a *Symposiarch*, *Archiposia*, *Arbiter bibendi*, or toast master, chosen by the throw of a die; the successful throw, being supposed to be regulated by Venus (*Quem Venus arbitrem dicit bibendi*): for the ancients also, were "wont to entwine, the myrtle of Venus with Bacchus's vine." Sometimes they adopted the silly practice of drinking a Cyathus* for each letter of their mistresses' name: *Nævia sex Cyathis, septem Justina bibatur.* I do not recollect any other specimen of their toasts, excepting the girls they were enamoured of.

Vultis severi me quoque sumere
Partem Falerni? Dicat Opuntiæ
Frater Megillæ, quo beatus
Vulnere, qua pereat Sagitta.

Mankind however, were much addicted to getting drunk, as we find in every part of history from Noah to Holofernes, from Alexander the Great to the tippling philosophers of Lucian's supper; without the hospitable excuse of Horace, *Recepto dulce mihi furere est Amico.*† They complained grievously of the effects of drinking. *Quo me Bacche rapis tui plenum? Evoe, Evoe, parce pater!* and so forth. These are symptoms of acid wine and head-ache. They probably knew not how to regulate the fermentation; they had no brandy to mix with their wines, to counteract the tendency to acidity: they drank their wines too new; for Horace seems to consider the four years old wine as a treat, *Deprome Quadrimum.* Nor were their wines clear, nor had they any cocks or spigots.

* This would be hard work, if, as Dr. Adams [Rom. Antiq.] supposes, the Cyathus held a quart.

† Expressed with much greater spirit in that fine old song "Welcome to Paxton, Robin Adair."

I will drink wine with you Robin Adair,
I will drink wine with you Robin Adair:
Rum-punch, ay, and brandy too:
By my soul, I'll get drunk with you—
Why did'nt they come with you
Robin Adair?

But enough of the ancients; let us follow Horace's model of a good epic poet, *In medias res semper festinat:* shew me at once the way to your cellar; if it be not as well furnished as Mr. Paymaster Rigby's or old Q's,* we will suppose it to be so.

What is this? Malmsey: good.

"Come broach me a bottle of rich Malvoisie,†

"Tis the boast of the Marmion tavern."

But this, like the Constantia, (the cape wine), Tokay, &c. is good only as a cordial or to give flavour to other wines, particularly the north side Madeira. It does not equally improve the south side wine. I think it is better kept in bottles than in casks.

When a wine is kept in a cask, three things are to be considered: what is the wine: what is the cask: where is it kept?

The effect produced by age on cask wine is this: the cask is porous, and there is a constant and gradual, though slow evaporation from the wine through the pores of the cask: the strong rich wines become concentrated, mellowed and improved in all respects; except that, if the wine be remarkable for any fine or peculiar flavour, that flavour will gradually be weakened, though the fullness, richness, and mellowness of the wine, will be improved. Hence, Tokay, Cape wine, Malmsey, the padre Ximenes, and Pachioretti Sherry, and the first qualities of Calcavella, are best in bottles after they have remained four or five years in the cask. These are the cordial wines; the wines to drink a glass of, after the course of sweet-meats, bon-bons, &c. and are certainly finer cordials than Noyau, Mascarille, Eau de Garuce and that class of spirituous impregnations.

Another consideration is, what is your cask? New oak gives an astringency to wine, in consequence of the gallic acid and the tannin of the wood being dissolved, which to me is extremely disagreeable except in port wine: and even that is better without it. New oak, is excellent for new rum and new gin; because

* The duke of Queensbury, lately deceased.

† Malvoisie. This is a name given to three different kinds of wine. 1st, It is the wine of Malvasia, the ancient Epidaurus; but better made in the island of Candia. 2dly, It is a Muscat wine from a grape grown in Provence. 3dly, It is the Malmsey of the island of Madeira. Malvasy, Malvisy, Malmsey, are names synonimous. There is a French Muscat grape also, called Malvoisie, a table fruit, of which wine is not usually made. It is not uncommon in the hot-house vineries of England. The Malmsey-Madeira, is the wine to which the name of Malmsey ought to be confined.

these liquors frequently contain a deleterious acetite of lead, which the gallic acid throws down; and this may also be the case where leaden worms are used in the distillation of brandy, particularly Spanish brandy; but for wine, most certainly old casks if sound, are greatly preferable.

Where do you keep your casks? The cellar is good, for wines that are not required to be full and luscious. Almost all the French and German wines, will sour in a warm temperature. A cellar uniformly about 50° of Fahrenheit is the best situation for them. Port wine requires a temperature of about 60 degrees. In England the best wine merchants keep a stove in their cellars. But Burgundy, Claret, Champagne, Vin de Grave, Vin de Chablais, Rhenish or Moselle, would be apt to turn sour in a warm place, especially if the warmth was not steady. Hermitage, Burgundy, Claret, Port, Florence, Sicily wines, lose colour, and flavour too, in casks, if they be exposed to alternations of heat and cold. Thin-bodied wines cannot bear it. There is not saccharine matter and mucilage enough to retain the strength and flavour: the body of the wine itself evaporates.

Madeira, Sherry, White Port, Lisbon, Malaga are improved by warmth: they bear also exposure to alternations of weather; by gradual evaporation they become stronger, richer, mellower; and a garret is better for them than a cellar.

In nine years, a pipe of Port wine kept in a cellar averaging from 42 to 50° of Fahrenheit, had lost the Port wine flavour, was of the colour of Madeira, and had diminished by evaporation exactly nine gallons: but was not in any degree sour. Madeira in a garret, I fancy would lose in rather a greater proportion; but less than Lisbon. For the richness and fullness of the wine, impedes but does not prevent evaporation. Casks so exposed to the warmth of summer weather, should be frequently examined. A good substitute for the common cock is a desideratum. The brass cock, is apt to collect verdigrease: the cedar spigot and faucet, must be long boiled, and soaked in brandy before it can be trusted: the spigot and faucet bushed with white metal, is bad; the metal is acted on by the acid of the wine: the quill is too slow. The persons who grind glass stoppers for experiments on air, could easily make a glass cock, or spigot and faucet. The iron hoops of a wine cask should be painted.

The best fining for wine of any kind is half a pint of *skim-*

med milk, beat up with the white of one egg, and then gradually with a pint of the wine, for a quarter cask.

No wine should be bottled, till it has been fined, and till it has remained four or five years in the cask. If the high flavoured red wines stay longer in the cask, they lose colour and flavour. The change the wine undergoes in the bottle (called sickness, which continues in newly bottled port wine from four to six months according to the fullness of the bottle) depends, if the bottle be well corked, on the space between the cork and the wine; for this is all the air the wine has to act upon. If the bottle be filled nearly up to the cork, little change will be made in the wine: hence if wine be bottled, that space ought to be left greater in new than in old wine. By thus acting upon the included air, a gradual mellowing of the wine takes place, and the tartar with a small quantity of the colouring matter subsides. In red wines, the peculiar flavour is contained chiefly in the colouring matter, which exposure to cold precipitates: that colouring matter, depends usually, not always, on the skin of the grape.

No cork should be used, till its soundness be examined; till it be well boiled in clean water; it should be driven by a machine under the direction of a man who is by trade a bottler of liquors; the bottle should be placed on its side. Never bottle your own wine or leave it to your servants, if you can help it. Remember, they who make it their business to do any thing, do it better than others who have but occasional practice.

Having thus made en passant, some general, and I hope useful observations, I return to Malmsey, which the French (who have no wine so good) call Malvoisie.

It is too rich to drink alone. From one twentieth part to one tenth part of old Malmsey, very greatly improves the common Madeira wine. The vino tihnto, a coloured wine, a Tent wine of Madeira, is *I believe*, a species of Malmsey not old enough to have yet lost its colour. I consider this as the old sacramental wine of the church of England.

Common Madeira may be greatly improved, and is so when wanted for immediate drinking, by a small quantity, (a desert spoonful to a bottle) of well clarified syrup of the finest loaf sugar. I believe in addition to this, it is not unusual to put a teaspoonful of a filtered vinous solution of isinglass in good Madeira. These give a fullness, a richness, and a silkiness to the wine, that to my palate is very grateful. But the isinglass is apt to precipitate on standing and exposure to the air.

Your next cask is *Madeira*. Is it London particular? Is it bill wine or barter wine? Is it Cercial? From the north, or the south side of the island? The London particular, is the highest priced wine for the London market: next to that is the bill wine, sold for bills of exchange: next to that is the barter wine, exchanged for goods. The wine of the south side of the island, as the Cercial wine, is much the richest: the northern side is comparatively harsh. Wine is made up in Madeira, by mixing, 1st, a certain quantity of old with new wine: 2d, a certain quantity of Malmsey with the common wine: 3dly, a certain quantity of north side with south side wine. The more old the more Malmsey, the more south side wine, the better and dearer is the mixture. Clarified syrup is a frequent substitute for Malmsey. Teneriffe is, I believe, lately, introduced as an adulteration.

All wines are vinegars as you say. But the older, the fuller, the richer the wine, the more wholesome is it, and the less apt to produce indigestion, heart-burn, and of course gout.

Madeira should not be bottled: frequently the ullage is the best part of it. Madeira is adulterated, by Teneriffe, by Sherry, by Lisbon, by Malaga, by Fayal. Sherry hurts the quality of the wine least, but the Sherry flavour cannot be disguised. Teneriffe spoils it in flavour, and in body. The twang of common Lisbon is detestable; so is Malaga unless very old and very dry. Fayal does not deteriorate the flavour, but it renders the wine meagre.

The harsh, subacid Madeira commonly met with, is extremely unwholesome. A good judge, will prefer the smooth, full, silky wine; though I confess this is a sensation frequently given as I have said before, by a slight admixture of clarified sugar. It approaches however nearest to the full rich south side wine; and is less apt to disorder the stomach.

The clarified sugar, should be of the best double refined, dissolved in clear pure water, boiled with the white of egg, and filtered through a flannel jelly bag. The isinglass addition, I suspect only, from my own observations and experiments, but I think I have detected it. A solution of terra japonica, will always throw down isinglass or any other animal gelatine.

You have *Teneriffe* there. Very old Teneriffe is drinkable. I have tasted none good for a sitting. Common Teneriffe ought not to find admittance, unless in the vaults of a professed wine merchant. If not the *Vile Sabinum*, a common homemade wine, it is not much better.

Marsala. A strong full bodied wine; heady; devoid of flavour. It is from the Madeira grape planted in Sicily, which has degenerated. While at Madeira the Rhine grape is so improved as to produce the Cercial. Malmsey in small proportion with Marsala and north side Madeira makes a good wine.

Sherry. The sack of Shakespeare's time, was, a mountain wine brought into the town in skins, *sacs*: whence the name "mountain," commonly used in England for Malaga. Sack was either the sac wine of Xeres, or of Malaga; the former was the Sherris-sack, the latter the Malaga-sack. 2nd. part of Hen. 4, act 4th. Sir John Falstaff says,

"A good Sherris-sack hath a two-fold operation in it; it ascends me into the brain, dries me there all the dull, foolish and crudy vapours which environ it; makes it apprehensive, quick, forgetive, full of nimble, fiery and delectable shapes, which being delivered over to the voice, the tongue which is the birth, becomes excellent wit. The second property of your excellent Sherris, is, the warming of the blood, which before, cold and settled, left the liver white and pale, which is the badge of pusillanimity and cowardice; but the Sherris warms it, and makes it course from the inwards to the parts extreme; it illuminateth the face, which as a beacon gives warning to all the rest of this little kingdom, man, to arm; and then the vital commoners, and inland petty spirits, muster one and all to their captain the heart, who great and pufft up with this retinue, doth any deed of courage; and this valour comes of Sherris. So that skill in the weapon is nothing without Sack; for that sets it a-work; and learning a mere hoard of gold kept by a devil, till Sack commences it, and sets it in act and use. Hereof comes it that prince Henry is valiant; for the cold blood he did naturally inherit of his father, hath like lean, steril, and bare land, manured and husbanded and tilled with excellent endeavour of drinking good, and good store of fertile Sherris, that he is become very hot and valiant. If I had a thousand sons, the first human principle I would teach them, should be to forswear their potations and to addict themselves to Sack."

Hence it appears that Sack, is the genuine name; and that Sherris Sack, Sherry or Xeres (Yery) is one (and the best) kind of Sack. Doubtless it is so: the Padre Ximenes (Yemanes) and the Pachioretti Sherry, often to be found in the London market, are fully equal to Malmsey Madeira: but no one can tell what good Sherry is, from the wine so called, usually imported in this coun-

try. Sherry will bear warmth, and gradual concentration equal to Madeira. But the first quality of it should be bottled in due time to preserve the flavour, which in fine Sherry is well worth preserving.

Colmenar, is a cheap sound wine, but the flavour is very inferior.

Lisbon: white Port. If these wines be kept till they are old and dry, they are tolerably good: but once for all, a judge of wine, and a judge of its effect upon the health, will confine his drinking chiefly to Madeira and Sherry of good age. These in moderate quantities, (and I should consider a pint daily and habitually, as beyond the scale of moderation) will probably do good. Other wines may be taken occasionally; but all others are in my opinion decidedly inferior. Dr. Nesbit was right when he translated Falernum by Madeira.

The *Calcavalla* Lisbon, is the highest and best flavoured wine of the kind; but not fit for a beverage to sit down to.

All this remark you know would be useless at a French table, where a bottle of meagre Bourdeaux is set before the guests, and once, or at the utmost twice, during the continuance of a two hours' dinner, a glass of the finest Bourdeaux, of Constantia, or Malvoisie is sent round: the desert finishes with Noyau, Mascarille or some of the Martinique liqueurs, and the guests adjourn to coffee. But in England, and with us, it is of great importance to know what kind of wine we can sit down to for an hour, with most pleasure to the palate, and least ill effect upon the health; remember Plutarch's advice, *ei oinos esti kakos eis numphas kataphugein:* if the wine be bad, fly to the tea table, as Dubois in his "old Nick," well translates it.

Is your cellar supplied with French wines? For a well appointed cellar cannot be without them. Your Hermitage, your Bourdeaux, and Sauterne; your Vin de Grave and Chablais, you import in casks: your Burgundy and Champaigne in bottles.

Vin de Grave, of the first quality I have never seen here: it is a well flavoured, rich, gold-coloured wine, worth attention; but the inferior qualities are not worth importing: nor in my opinion is Chablais.

Hermitage. This is the fullest bodied red wine that France produces. It is a sound good wine, of high flavour. It is particularly useful to give body to and develope the flavour of claret (Bourdeaux,) and a small quantity greatly improves Port. But it

is well worth drinking alone; and when bottled at a proper age, is a fine wine; equal if not superior to the best red Port.

Bourdeaux wine: Claret. This last is the English name: the French call it Bourdeaux wine. Thirty years ago, when what would be called passable Claret was bought at Bourdeaux for 800 livres the Barique, the London purchasers gave 2500 livres. The best qualities of Claret, are La Fitte, Chateau-margo, St. Emilien and St. Julien, vineyards within the district of Medoc, near Bourdeaux.

Good Claret, (seldom imported here) is a fine wine. It is among the best wines to sit down to, as a bottle of it may be drank without intoxication, and the odour and the flavour of the finest kinds, are both extremely agreeable. But even good Claret will bring on a fit of the gout, with persons liable to that disorder sooner than almost any other wine. The better the wine, the less apt is it to produce this effect.

For the continental market, Claret is mixed with juice of fresh violets and hermitage: for the English market, Brandy is added to it; and the wine is the better for the addition.

Young men, that is, men on the right side of forty, may drink Claret with impunity, if they attend to moderation, and have no disposition to gout or stone. Otherwise, they had better keep close to Madeira and Sherry.

Claret should be kept in a cellar, on the side; in the temperature of about 50°. The flavour, will gradually dissipate from the cask, and too much warmth, will be apt to sour the wine.

Burgundy. I consider this when good, which is a rare quality here, as the best of the French wines. It is of good body, but extremely delicate and hard to be kept. The flavour is higher than either Hermitage or Claret. I have kept it in bottles three years in wet sand in a good cellar of temperature 55°. For want of care in bringing it over here—from the corks being permitted to grow dry—and probably also from the inferiority of the wine imported, it is generally "pricked," or with a tendency to acid decomposition, in which state, it is not easy to find a more unwholesome beverage.

Champagne. This is either tinted (*oeil de perdrix*) or colourless: either *mousseux* sparkling, or *non mousseux*, still Champain. It is a thin wine of delicate flavour. The sparkling Champain, is made so, by closing it up in very strong tight casks, before the fermentation is fully over. In this state, it is made to

combine with much carbonic acid gas; which makes it act quicker on the stomach, and renders it sooner intoxicating. It is a pleasant wine occasionally, but meagre, and one that quickly palls upon the appetite. It is far inferior to Hermitage, Burgundy, or Claret, and not greatly superior to good English Perry. Half Sauterne, and half Seltzer water, is a beverage nearly as good as Champain.

Sauterne. A wine of delicate flavour, little if at all inferior to the Champagne non mousseux. Considering its quality, it is the cheapest of the French wines imported here; and if like all the rest of the French wines, it did not produce tendencies to gout and stone, it would be a very desirable table wine. But there is no French wine that is not bad for persons who have tendencies to gout.

Chablais. Tired of Champagne and Claret, this wine of moderate flavour and moderate strength, became preferable to me as a regular beverage to the others. But it has no merits that should induce its importation. It is superior to Fayal.

The common *Rhine wine*, and *Moselle wine*, are little superior to good cyder. I have drank repeatedly Hock of 1726, and Hock of 1749, which being kept in large quantities, had not become vinegar: it was comparatively to the common Rhine wine, an excellent liquor. But Hock is gouty: it produces stone and gravel, it is perceptibly an acid wine, and fit only, to drink after rich soup to clear the mouth; for which purpose only it is usally introduced in England, in glasses fantastically imitating the course green tinge of the German wine-glass. Punch after strong soup is quite as good. Common Hock is not much better than strong cyder.

Of the Italian wines, we import none, I believe except those of Sicily: the red wines of that country are cheap, and for their price very good. Certainly superior to the common clarets. So is Florence. The *Lachryma Christi* and *Cota-roti*, we know little of here.

Port. Vin d'Oporto. Sir Paul Methuen, and the woollen manufacturers of Leeds and Halifax, have been the chief causes why Port has become the national wine of the English. It has arisen from the shopkeeping notions of the British statesmen, and the persevering representations or rather misrepresentations of the manufacturing interest. To mercantile monopoly, and to manufacturing monopoly, all the great interests of that nation have hitherto been made to bend.

All the first Port wine is regularly bought up for the London market, where there is sale for a much larger quantity than Portugal produces. It is made up in Portugal with brandy, but I do not know of any other admixture. Hermitage improves it. Few wines admit of so much difference in quality; nor is the Port wine imported into this country, to be compared to the English Port. There may be occasional exceptions, but there are very few. The price of Port wine, has gradually risen in England, within thirty years, from 26l, sterling the pipe, to 100l.

In that country, where the management of it is well understood, a pipe of Port, is fined with whites of egg, within a short time after it is deposited in the cellar. It stays there from 4 to 6 years. The cellars in England are all arched with brick; the bricks are *grouted*, that is fresh mortar in a thin paste is poured into all the joints so as to fill up every interstice; a process in my opinion indispensible to every arch of brick or stone. The arch is then covered with a coating a foot thick of clay well beaten with beaters. It is thus rendered impervious to moisture. If the cellar walls are not perfectly dry they are cased with rough boards. Brick partitions at right angles with the wall, are built so as to divide each side of the cellar into bins, calculated each to hold a pipe of wine in bottles, or about 50 dozen of 14 to the dozen. The partition walls extend from the cellar walls about four feet, or a convenient distance for a man to reach from the front to the back part of the bin. The front ends of the partition walls are finished with upright square posts, grooved for boards to slide in, which form the front of the bin. Frequently the front is of brick, and a lid with a padlock secures the whole bin from the depredation of servants. The wine is placed on dry saw dust on its side. It is never touched till about nine months after it has been bottled. Care is taken to exclude currents of air; so that the temperature shall be kept as nearly equal throughout the year as possible. The bottles when wanted are carefully brought up in a basket long enough to hold two bottles endwise, on their side, the crusted side downwards, undisturbed. The corks are drawn while the bottles are still kept in a state of inclination, not upright. The cork screw should be the compound double patent screw, that draws the cork without pulling and tugging, or any other effort than that of turning the screw itself. The cork being drawn, a silver anti-guggler is inserted, so as to admit the

external air to the bubble of air included at the upper side of the bottle; the wine is thus decantered without the sediment being disturbed by the conflict of the wine going out, and the air coming in. The wine is strained into a decanter through a silver strainer to which fine muslin is fitted, and is drawn off no nearer than to leave a glassful *at least* in the bottle.

The wine in winter time, is then set before the fire, and in summer time it is never cooled. Cooling Port or Claret, makes it muddy, and totally destroys the flavour. A good judge of wine, and who knows how to enjoy it, will never cool fine, high flavoured wine of *any* kind below 50° of Fahrenheit: in summer time in this country, the sensation of coolness, is pleasanter than the sensation produced upon the palate by middling wine. But it is a vile and a vulgar practice, to destroy the flavour of fine wine by cooling it down to 33 or 34° by means of ice, even should the thermometer be at 96°. Destroy the taste of *bad* wine, by ice, if you please; but a man who does so by *fine Madeira*, does not deserve it.

At an English table even of fashion, the every-day wines, are either Sherry or Madeira at dinner, and Port or Claret afterward. In summer, both. Lachryma Christi, Cota-roti, Hermitage, Burgundy, Champain are the wines of ceremony only.

But the English seldom prefer Claret to Port: the Irish seldom prefer Port to Claret. The English drink no liqueurs: Muscadel and Frontiniac, are sometimes produced to the ladies as sweet-meat wines; but not generally.

The precautions in keeping wine that I have enumerated, are not exclusively confined to high fashion or great wealth: every English gentleman of tolerable fortune attends to them as indispensible. Our different practice in this country, has arisen from necessity. Our immediate ancestors could not afford the trouble or the expense, nor had they the taste to require, the careful bottling, corking, and keeping of wine: but with respect to Madeira, their accidental practice has been in all respects an improvement. An Englishman does not understand Madeira; which after all is *the* wine, the *Falernum* of the moderns. Nor does an Englishman understand the practice of smoking, except in the lowest beer-houses. I acknowledge a segar is frequently a luxury: so to a sailor is a quid of tobacco; but the one indulgence and the other, are so inconsistent with neatness and cleanliness, that in decent society they ought to be renounced. I hope the time will never again arrive, when it shall be necessary to admonish the

beaus of Philadelphia, that segars are not admissible in the ball room on Washington's birth day.

Thus managed and thus drank, Port is a very fine wine; and satiates far less than any other red wine; but after all, it is not Madeira.

The Southampton and Guernsey Port, (that is, the Port generally sold there, and frequently smuggled there) is a thin kind of wine, pleasant but without body, and without merit.

When wine is drank, the glass for red and the glass for white wine should not only be different, but of different forms. A full small glass of wine, is not half so agreeable, as the same quantity out of a larger glass. There is an association of gluttony, and vulgarity, and slovenliness in a full glass. Bumpers should be banished to bacchanalian parties, which are never epicurean. The stem of the glass, should be long enough easily to admit two fingers without touching, and soiling the bulb. The glass should not only be the finest flint, clear, without colour, blebs, or blemishes, but thin. Half a glass of wine (and more should seldom be filled) has more odour and flavour, in a tolerably sized glass, than the same quantity in the form of a bumper. All ornaments about a wine glass, are inelegant, bourgeoise; they savour too much of finery. The character of a gentleman's establishment, is *simplex munditiis*. The only use of a cut border to a drinking glass, is as a memento, not to fill it beyond the lower edge of the ornamented border.

Hence, also, napkins at dinner, and doyleys after, are necessaries: not so, water glasses. The use of them like the four-pronged silver forks, arises from an affected imitation of foreign customs: after a French dinner, where the fingers perform much of the duties of a knife and fork, water glasses are necessary: but not after an English dinner at a genteel table; where meat is seldom touched with the fingers: where the dishes are solid for the most part, and the meat is cut, not torn: where the right hand is occupied by the knife and the left hand by the fork: while at a French dinner, the right hand holds the silver fork, and the left hand a piece of bread, while the knife is deposited in the pocket, being comparatively little used. Not to mention the associations of uncleanliness and indelicacy connected with the use of water glasses. Where the dinner is a mixture of French and English cookery, the silver forks are not out of place.

If possible, the room to drink wine in, should not be the dining room: and a glass or two of rose water sprinkled upon the carpet, is a cheap luxury.

Thus have I extended perhaps to an unconscionable length, my remarks on wines. I have confined myself to the wines usually imported. Of homemade wines, I shall present you with my experience hereafter.

I have in the beginning taken the licentia poetica, (or if you will forensica) that is, the licentia fingendi, and supposed your cellars filled with choice liquors instead of choice books. I wish you had more abundance of the first, and more room for the last. I know you are amateur of good living in all the *good* senses of the word: nor should I greatly object to apply to you, Akenside's picture of the Teian Bard.

I see Anacreon smile and sing,
His silver tresses breathe perfume,
His cheeks display a second spring
Of roses, taught by wine to bloom.
Away deceitful cares away!
And let me listen to his lay.

Adieu my friend.

EPICURI DE GREGE PORCUS.

LETTER SECOND, TO THE EDITOR.

QUÆDAM DE VINO. ON WINE.

[I insert this letter, which was intended for the 4th number, in the present, because I am prejudiced in favour of bringing together, as much as possible, all the communications on one subject. T. C.]

My Good Friend,

I promised you some information on homemade wine; the *vile Sabinum.* Of the many English and American receipts for these liquors, there are none worth a cent. Nor is the practice, in this respect, of even Mr. Cooper of New Jersey, entitled to more approbation. I shall in this essay tell you, not what I have read, but what I know, partly from my own experience, and partly from the experience of those on whom I can depend.

Wines may be made out of apples, pears, quinces, cherries, currants, gooseberries, blackberries. Out of the fox grape, the natural small white grape, the small round black grape. Out of the imported Sweet water, Claret and Burgundy, and Rhine grape. Wine can be made out of the Malaga raisin.

In the southern states, it can be made out of the Constantia, and out of the grape produced by sowing the common jar raisin. But it has not been so made as yet.

Cyder. The method of making cyder is sufficiently known in this country among those who make it a business to sell it in the seaport towns. The richest cyder I ever tasted, had a gallon of good apple brandy, put to a quarter cask at the commencement of fermentation: it was made out of high flavoured apples.

The common cyder-royal, cyder and honey, and cyder-wine, made by boiling the juice of the apples, are very bad. Cyder is made more vinous, by pouring boiling water on Malaga raisins, steeping them for about thirty hours, and putting the pressed juice of about half a bushel to the quarter cask of apple juice, previous to fermentation, with about half a gallon of brandy. This is cyder-wine and worth attention. The goodness of cyder greatly depends upon racking it. The casks should be previously sulphured and rinced out with brandy.

Perry, is made like cyder. I have tasted none good in this country. Our friend, Mr. P. at your persuasion, had two quarter casks of Perry made of the juice of the common egg pear, but it was thin and meagre. The Perry of England, is little, if at all, inferior to Champain: and very superior to common cyder.

Quinces. I have not tasted this wine. A good judge informs me, that there are very few wines of any description equal to it in body and flavour. Doubtless a small proportion of quinces would greatly improve cyder.

Cherries. In Philadelphia, the wine of the morella cherry, coloured, is sold often as red Port. I suspect it is too harsh to be wholesome or palatable.

Currants. All homemade currant wine is made too sweet. To one gallon of the pure juice of Currants, add one gallon of water. To each gallon of the mixt liquor put 2½lbs. of the best clean Muscavado sugar: ferment with half a pint of yeast, in a cool cellar, from 20 to 30 hours, or till the fermentation is over, and the head begins to fall; filling up the cask from time to time as the liquor works out of the bung-hole. It may be known to have suffi-

ciently fermented, when the head of yeast at the bunghole begins to subside. Add to the quarter cask two gallons of good brandy, or half a pint to each gallon of wine. Let it remain bunged up for four months; then fine it with the white of an egg beat up in skimmed milk. In a twelvemonth rack it off in a clean cask, rinced out with a little brandy and water. This wine, to be *good*, ought to remain in the cask at least four years after racking. 1 cwt. or 112lbs. of fine ripe currants, will yield near 10 gallons of juice. Six pounds of sugar will add half a gallon to the bulk of the liquor. A mixture of about one sixth black currants, greatly improves the flavour. For smaller quantities proceed thus:

Take equal parts of currant juice well strained through linen or flannel, and water. To 10 gallons of the mixt liquor add 25lb. Muscavado sugar, previously dissolved in the water. Add about a gill of yeast; let it ferment in a cool place about 24 hours, or till the fermentation is over. Beat up the white of an egg in a quarter of a pint of skimmed milk. Stir it about well. Bung it up: in four months rack it off, and add a quart or three pints of brandy.

The wine from Gooseberries. Dr. Clark is right, in his Travels to Russia, when he says, this is equal to any Champain. But gooseberries do not grow so well in America as they do in England. Gooseberry wine made sweet, and flavoured with the blossoms of elder flowers, is not a bad imitation of Frontiniac.

Blackberries. I do not know any thing of this wine; I have tasted the wine made from

Elder Berries; but it has no qualities to recommend it.

All the writers on made wines, strongly exclaim against brandy being put into them: this is from a silly and affected regard for health and sobriety: *all wines* are the better for it. When Port wine, or any of the thin wines are in danger of becoming acid, there is no better remedy for the evil than half a gallon or a gallon of good brandy to the quarter cask. *Experto crede Roberto.* We hear a great deal of exclamation amongst physicians, against the deleterious effects of fermented liquors, particularly of ardent spirits. They might as well talk of the deleterious effects of arsenic or opium. They are all poison *in excess;* they are excellent and invaluable remedies in moderate doses. If a man drinks to excess, it is a gradual poison, greatly inimical to muscular strength, and also to mental vigour; and so it is if he eat to excess; but in moderation, wine greatly aids both the one and the other; independent of the pleasurable zest it gives, even to the

best society. I do not find that water drinkers live longer, or are more free from maladies, than those who enjoy their wine in moderation; and I am well persuaded, that the latter class do not, in general, exceed so much in the article of eating.* For a labouring man, beer may be better than ardent spirits; but bishop Warburton was right when he said, "they who drink beer will think beer." For my own part, I confess, I entertain something of the common prejudices against obstinate sobriety, and I fully accord with Sheridan's song.

Truth they say lies in a well:
  This I vow I ne'er could see:
Let the water drinkers tell,
  There it always lay for me.
But when sparkling wine went round,
  Never saw I falsehood's mask,
But still honest truth I found,
  At the bottom of each flask.

The Fox Grape. The pure juice of the ripe fox grape to my own certain knowledge, makes a full bodied, strong, well flavoured Madeira-coloured wine, which in my opinion, if these grapes were cultivated, would fully equal the best Madeira. Some juice was expressed out of the fox grape, by part of my own family; it was strained; it was put by in a decanter: it was left with the stopper out, exposed to the frost out of doors through the winter. It was put by with the stopper out, in a sideboard till July 2; of the year 1802. There was a mother on top of the wine in the decanter. It was somewhat hard, but well flavoured, full bodied, strong, and equal to good Madeira. I drank some wine of the fox grape afterwards made at Havre de Grace. I suspect it was not the pure juice; it was a tolerable wine but thin. The fox grape, is in its growth, in the pulpiness of its fruit, and in many of its habits much like the Constantia grown in Pennsylvania. I am well satisfied it is worth careful cultivation for wine. No imported grape is to be compared with it for this purpose.

The small round white and red wild grape. I know nothing of the wine from these. If treated as apples are for cyder, I make no

* Dr. Darwin, who left off wine when the gout compelled him, used to indulge afterward in eating, and would swallow, without remorse, his bowls of rich cream, while he would inveigh against the smallest portion of fermented liquor.

doubt they would make a good wine. Let it be remembered, that the more juicy, and the more pleasant a grape is for the table, the worse it is for wine. Such grapes make thin, meagre, acid wines, in all the instances I have known.

The imported, Sweetwater, Claret and Burgundy and Rhine grapes. All these are too juicy to make wine of. They require sugar and brandy. The wine made at Mr. Henderson's at Huntingdon, the wine made at Harmony, near Pittsburgh, the wine made by the Swiss settlers near St. Genevieve, has all the same fault. It is too meagre: it wants body; sugar and brandy would greatly improve it. The Harmony wine, if made Mousseux, would not be inferior to Champain. Even in Champagne, they are frequently obliged to add both sugar and brandy; and the wine we so greatly prize, owes its goodness to materials as easy to be procured here, as they are in Champagne.

Constantia. The Constantia grape grows in Pennsylvania, but for want of sun it is pulpy, not juicy, and it ripens late. I am fully persuaded, that this grape and the fox grape (equally good) are the stock-fruit for wine in this country. I earnestly recommend them to the States south of this.

I close these remarks by stating my full conviction that *good* wine can be afforded in America, cheaper than good cyder; can be made to greater profit, and in greater plenty.

Malaga Grape. Two thirds of all the white wines sold at the inns and taverns of England, the Madeira, Sherry, Calcavella, Lisbon, White Port, and Mountain, (as well as the White wine vinegar,) are manufactured at home out of the Malaga raisin. The present Harry Beaufoy, Esq, who succeeded to his father's vinegar-yard and wine manufactory, sold out his establishment for a life annuity of six thousand guineas a year.

I know not the processes for imitating each of these wines, but one essential part is, that the wealthy manufacturers of England can afford to keep their home-made wines, till age makes them really good.

It would be a manufactory well worth establishing in this country. The method of making White vine vinegar out of cyder and Malaga raisins you have given accurately in the port folio.

I have now presented you with my desultory remarks on wine; but I have somewhat more to say, better worth your readers' attention than any thing I have yet said on the subject.

I am an advocate for drinking wine, for the sake of good company, for the pleasure of drinking it, from motives of conviviality, and not merely as St. Paul recommends it, for the stomachs' sake. But I should not be an epicure, if I were not to insist on habitual moderation: this is the mark and the criterion of the *gentlemanly use* of every indulgence; nothing betrays vulgarity so much as excess. People who are not accustomed to good living, gormandize when they meet with it: those who are accustomed to it, have no temptation to exceed the bounds of moderate enjoyment. But I fear that my notions of moderation do not coincide with common practice. I am fully persuaded that wine as an habitual beverage much short of any thing like intoxication, lays almost the only foundation for the *gout* and *stone*, of the decline of life: these are one and the same disorder, so far as remote and proximate causes are concerned in producing them. I know of nothing that can excuse excess in drinking, but a typhus fever for which physicians prescribe it, or the intolerable pressure of recent misfortune, for which Horace, and after him Burns prescribes it on the authority of Solomon; *Dissipat Evius, curas edaces.*

"Give strong drink unto him that is ready to perish, and wine to those that be of heavy heart. Let him drink and forget his poverty, and remember his misery no more. Prov. xxxi. 6. 7."

Gie him strong drink until he wink,
  Whae's sinking in despair;
And liquor guid to fire his bluid
  Whae's prest wi' grief an care.
There let him bouse and deep carouse
  Wi' bumpers flowing o'er,
Till he forgets his loves or debts,
  And minds his griefs no more.

I was led into this train of reflection, by a passage in the Edinburgh Review for November, 1811, of which an account is given of some experiments of Mr. Brande on the quantity of alcohol contained in wine: I shall give the substance of those trials, with the obvious remarks of the reviewers, and add to them the experiments which I have seen you make on the same substances. The pleasures of the table consist so much in the circulation of the bottle, and the subject is of such great importance to health as well as to pleasure, that I can not think, this dissertation will be void of interest.

Alcohol is pure spirit of wine. M. Fabroni, an Italian chemist, being unable to detect alcohol in wine by any process previous to distillation, was of opinion that the alcohol procured from wine, was formed in it during distillation. Mr. Brande's experiments tend to an opposite conclusion; and seem to prove, that all the alcohol produced by distilling wine, existed as alcohol in the wine previous to distillation. On this point, I am careless who is wrong, and who is right, although I have no doubt that alcohol in beer is formed from the Fecula, and in grape-juice from the saccharine part, during fermentation.

But in the course of these experiments, made on upwards of fifty different kinds of foreign and home-made vinous liquors, of the very best and purest quality that could be procured, and according to all evidence, free from adulteration, Mr. Brande procured as follows:—

Of alcohol or pure spirit of wine

from Rum -	53, 68 per cent.
Brandy	53, 39 ———
Holland's Gin	51, 60
Marsala wine	17, 26 to 25, 87
Port wine	21, 40 to 25, 83
Sherry	18, 25 to 19, 83
Madeira wine	24, 42
Claret	12, 91 to 16, 32
Tokay	9, 88
Hock	8, 88
Raisin wine	25, 77
Currant wine	20, 55

From this table it appears, that Rum, Brandy and Hollands, consist of about half spirit of wine or alcohol, and half water. That Madeira, Port, Sherry and Marsala, consist of about one fourth spirit or alcohol, and the rest, the vinous liquor with which the spirit is combined. Hence it follows, that every man who drinks a bottle of Madeira or Marsala, drinks about a pint of strong brandy. Now, any man who beside his porter, or brandy and water at dinner, will sit down to drink in the course of two or three hours, an additional quantity of a pint of brandy mixt with a pint of water, would be regarded as very careless both of his health and his intellect, yet, this is the case with every man who swallows his bottle of any of these strong wines. That the digestion is injured, and that the mental capacity is injured, that

nervous irritation, and muscular debility are induced by excess in spiritous, liquors there can be no doubt; and whether this quantity be excess or not, may fairly be left to the unbiassed judgment of the reader.

The preceding remarks are sufficiently obvious to every body, but the following additional observations, I owe to yourself.

The liquid that the alcohol is combined with in wine, is not near so innocent as water: it is literally in the very best wines, Madeira for instance, *Vinegar.* Wine is vinegar, holding in solution, alcohol, sugar, mucilage, and vegetable gelatine.

Every man who drinks a bottle of prime London particular Madeira wine, drinks a bottle of vinegar mixt with brandy. It is the same with Sherry, Marsala, Teneriffe, Lisbon; with Port, Claret, Burgundy, and Champain. I have tried them all.

All wines are made from the fermented expressed juice of the grape: and so is all vinegar. The fermentation is pushed a little further in vinegar than in wine, but the difference is only more and less acid: time and access of air, destroys this difference altogether, and converts wine into vinegar.

Now for the proof of this.

For the purpose of ascertaining the minutest portion of acid in any liquor, the chemist relies implicitly on paper or cloth dipped in the juice of litmus, or in the juice of red cabbage. The lichen or moss from whence litmus is made, is infused in water to which a very small quantity of a solution of pearl-ash is added, just sufficient to make the tinge rather blue than red.

Or, water is added to the red part of the skin of the stalks of red cabbage, and a small quantity of solution of pearl-ash is added, just sufficient and no more, to produce a blue tinge. This blue tinge is discharged by all acids; and a red colour produced, that encreases in intensity according to the strength of the acid, of which it is made the test.

Upon a piece of muslin or white paper thus tinged blue, drop one drop of common vinegar; at some distance, drop one drop of good wine of any kind; then (at some distance) one drop of good cogniac brandy; then one drop of Spanish brandy; then one drop of peach or apple brandy; then one drop of good rye whisky. The vinegar will give the strongest red tinge—the wine, the next in depth of colour—then the spanish, apple, and peach brandies—then the cogniac will be still weaker—and the rye whisky if good,

will hardly tinge the paper at all. Neither pure spirit of wine, or pure water, will produce any change of colour.

If there be any acid in the brandies, it is owing to the vinous liquor from which they are produced being carried into fermentation, and driven over by careless management in the distillation, which is commonly the case especially in Spanish brandy: and is so sometimes in whisky; but not so often. This is an experiment that any of your readers may try, and satisfy himself of the truth of.

After this, are we to wonder at the Dispepsias and Cardialgias —at the indigestions, the acid eructations, the heart burns, the gout, the stone, &c. with which great wine drinkers are generally afflicted in the decline of life?

Your opinion is, and I acknowledge that every day's experience seems to corroborate it, that the constant and regular introduction of so much stimulating acid liquor into the stomach daily, tends to produce the *habit* of acid secretion throughout the system; a habit that may be propagated and become hereditary: and this is the cause of indigestion, gout, and stone; and not any morbid action merely of the solids, unless produced by, and producing this acid character, this morbid stimulus of the fluids. Nine tenths in number of all the human calculi, consist of acid deposition. Those who are afflicted with these symptoms, must persevere in the exercise of walking; they must decidedly leave off wine; they must avoid ascescent food; they must habitually take magnesia, or volatile tincture of guaicum, or alkaline liquors such as soda water; and sedulously keep up an active state of the bowels—they must confine their beverage to weak spirit and water; and of spirits, gin and whisky are the most unfashionable, but indubitably the most wholesome. By these means, the duration of a threatening fit will be lessened, and future attacks gradually prevented.

In England, Porter is, and is deservedly, a favorite beverage but that is *draught* porter. In this country, bottled porter is a favorite drink particularly in summer; I never tasted bottled porter or bottled ale, that did not approach to vinegar.

Of all wines old and strong Madeira is the best: next to that, the Padre Ximenes Sherry and the Pachioretti. Acid as all wines are, I do not think that half a pint of generous wine daily, even habitually taken, would be attended with any ill effects; for some counteraction to acidity is afforded, by the quantity of animal food we

indulge in: but I am very sure that no man can drink a pint of vinegar daily with impunity, whether it be mixed with alcohol or not. He will feel it in the course of years: the maladies of the decline of life, will furnish severe recollections of past imprudence. Years bring infirmities enough; we should be upon our guard not to add to them.

Adieu for the present. PINE TE KAI TERPEU *Vive*, *Bibe*, *Vale*: that is, eat, drink and be merry, but in moderation.

I hope it will be long 'ere our friends will have occasion to repeat over your grave, or mine,

Scripsisti satis; edisti satis; atque bibisti,
Nunc tempus abire tibi est.——

Yours'

EPICURI DE GREGE PORCUS.

TO CORRESPONDENTS.

I am so frequently asked why I do not give information on subjects that have not yet arrived in their turn, that I think it right once for all to state my plan. I shall conduct this work for a twelvemonth, and if I and my publishers find a common interest in the concern, until my plan be completed.

I have dwelt longer on the articles IRON and STEEL than I mean to do on the rest, because they are of so much importance, so little understood, and so little information of value has been collected concerning them.

The scattered papers of so many volumes which I have brought together, contain more instruction than any single treatise or any two treatises hitherto published, in any language; and the value will 'ere long be appreciated, by those who are willing to give attention, and who seek for information rather than amusement; and should the work stop here, I have no hesitation in saying that I have been of public service, on the most interesting and important of all manufacturies.

I propose in future numbers to take up about 100 pages of each number with the following subjects, upon all which my collections are prepared; the result for the most part of my own actual observation of manufacturing processes, or of communications from persons actually engaged in the manufactures; where that is not

the case, I can safely promise the best information that books can supply. I do not undertake to confine myself strictly to the series of the following arrangement, but I am not inclined greatly to vary from it.

History of *steam* engines: methods of consuming *smoke.*

Manufactures dependant on *copper:* assaying, smelting of Copper ores: alloys of Copper; Chrystals of Verdigrease; Verdigrease: Verditer: Green pigments prepared from copper.

Manufactures dependant on *Lead.* Assaying and smelting of Lead ores: massicot: litharge: red lead: white lead: sugar of lead: refining of Lead for silver: Milled lead for boxes: alloys of Lead: Shot.

Manufactures dependant on *Tin.* Tinned iron plates: tining of Copper: tinfoil: tinning of pins: Bronze: Putty.

Manufacturies dependant on *Gold, Silver,* and *Mercury:* various methods of gilding, silvering, and plating: assaying: parting: silvering of looking glasses. Alloys of these metals.

Manufacturies dependant on *Antimony* and *Bismuth.* Pewter: white metal: Types.

Colour making. Carmine: red lakes: yellow lakes: copper-brown: Lamp, Ivory, Frankfort blacks: pearl white, spanish white, flake white, white from Barytes and Strontian: saxon blue: nankeen dye: brown, dutch and rose pinks: sap green; Scheele's green, french green, brunswick green, olympian green (vid. copper:) aurum musivum: ultra marine: smult: bice: cinnabar: vermillion: chromat of lead and of mercury: patent mineral yellow: cheap paints: stencils; coloured chalks: pannels for painters: oil cakes: colour mills.

Chemical drugs in the large way. Pot and pearl ash: pure alkali: soda; ammonia: oil of vitriol: spirit of salt: aqua fortis: cream of tartar: radical vinegar: acids of tartar: of lemons: of sugar: of benzoin: sulphat of potash, of soda, of magnesia: calomel: corrosive sublimate: unguent. mercur: red precipitate: preparations of Antimony: of Bismuth: muriat of barytes: elastic gum tubes: purification of Camphor: the common quack medicines: method of detecting adulteration in medicines: memoir on chemical manufacturies with reference to the law of nuisance.

Tanning, with the modern proposed improvements. The processes for making Turkey, Morocco, and Russian Leather. Dying and staining Leather.

Bleaching, Wool, Silk, Cotton, Linen, Paper, Stained prints.

Dying, Wool, Silk and Cotton.

Printing Calicoes.

Pottery: glazing of pottery: enamel colours for pottery.

Glass Manufactory: With an abridged translation of Loysel, and Bos. D'Antic.

Manufacture of *Glue: Isinglass: Starch: Hair powder: Wafers: Sealing wax.*

Gunpowder and the purification of Salt petre.

Manufacture of *Alum:* of common *Salt.*

Varnishes, particularly the actual manufacture of Copal Varnish in the large way.

Etching on Copper and Glass: *Aqua tinta: Staining* of wood and bones: *Marble* polishing, &c.

The above with other articles of the same general description, will occupy the greater part of each number: about sixty pages more will be filled up with such miscellaneous matter as may occur to me from time to time.

Should the above plan be reasonably well executed and encouraged, this work will go on; if not, the end of the year will close it, so far as I am concerned. T. C.

I have received from a manufacturer of stone ware at Charleston on the Ohio, a specimen of what is deemed a very valuable and secret cement for joining together pieces of stone. I have tried it, and it is made thus. Melt 3 parts by weight of Rosin with one part by weight of wax; when fully incorporated add to them while fluid, one part by weight of finely sifted well-dried brick dust. A little more or less rosin makes the composition harder or softer.

Dr. Doddridge of the same place has sent me a very useful pamphlet on the management of Bees, with an improvement on the structure of the Bee house, the mode of colonizing bees, and taking the honey without destroying the insects. The directions seem to me judicious and practicable. It is printed at St. Clairsville on the Ohio.

END OF VOLUME FIRST—NEW SERIES.

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